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Inventory of marine vertebrate species and fish-habitat utilization patterns in coastal waters off four national parks in Hawai‘i

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Acronyms:
NPS National Park Service
PACN Pacific Island Network
I&M Inventory & Monitoring Program
KAHO Kaloko-Honokōhau National Historical Park
KALA Kalaupapa National Historical Park
PUHE Pu'ukoholā Heiau National Historic Site
PUHO Pu'uhonua o Hōnaunau National Historical Park
NOAA National Oceanic and Atmospheric Administration
USGS United States Geological Survey
GIS Geographic Information System
GPS Global Positioning System
UTM Universal Transverse Mercator

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ABSTRACT

Marine vertebrates were investigated at four national parks in Hawai‘i in 2005; Kalaupapa National Historical Park (KALA) - island of Moloka‘i; Pu‘ukoholā Heiau National Historic Site (PUHE), Kaloko-Honokōhau National Historical Park (KAHO), Pu‘uhonua o Hōnaunau National Historical Park (PUHO) - island of Hawai‘i. In addition to an inventory of marine vertebrate species, fish-habitat utilization patterns of marine fishes were examined within each park. A total of 178 marine fish species were observed in the marine waters adjacent to all four parks, including 48 endemic species (27% of the total). Although the greatest number of marine fish species was observed for KAHO, the greatest density and biomass of marine fishes were observed at KALA. The highest average values per sample for assemblage characteristics (species richness, density, biomass, diversity) were observed for KALA which is characterized by large (up to three meters in diameter) volcanic rock boulders with high habitat complexity and low (<10%) coral cover. PUHO and KAHO had sequentially lower fish assemblage characteristic values and the habitat consisted of smaller volcanic rock boulders with higher coral cover. PUHE had the lowest assemblage characteristic values observed and most dissimilar species composition, due to a greater proportion of sand and degraded habitats. KAHO and PUHO had the most similar species compositions observed. Marine turtles, particularly the threatened green sea turtle (*Chelonia mydas*), were commonly observed in KAHO and PUHO, and also observed in KALA. Dolphins and whales were commonly observed in park and adjacent waters. The endangered Hawaiian monk seal (*Monachus schauinslandi*) was documented at KALA and has been observed at the other three parks.

INTRODUCTION

The National Park Service (NPS) established the Inventory and Monitoring program to scientifically document the range of features and resources within national parks as a basis for improved management. Marine ecosystems, particularly coral reef communities, present unique challenges for inventory and monitoring. Researchers frequently must work in difficult conditions in fragile communities where most organisms shelter in holes and crevices, often cryptically.

In order for management agencies to effectively manage their resources, these must be identified and their current conditions documented. Numerous marine resources have been in decline for decades globally (Bellwood et al. 2004; Pandolfi et al. 2005) and locally (Hunter and Evans 1995; Friedlander and DeMartini 2002; Smith et al. 2002). Today, coastal resources in Hawai‘i are facing unprecedented changes and declines due to numerous factors, particularly anthropogenic impacts, such as coastal development and overexploitation (*reviewed in* Friedlander et al. 2005; *see also* Lowe 1995; Smith 1993, Friedlander 2003). Marine vertebrates, especially fishes, have suffered enormous declines, estimated at over 90% globally for large predatory fishes (Myers and Worm 2003). The near-extirpation of apex predators and heavy exploitation of lower trophic levels in the main Hawaiian Islands from intensive fishing pressure has resulted in a stressed ecosystem that does not contain the full complement of species and interrelationships that would normally prevail (Friedlander and DeMartini 2002).

Declines in marine resources in Hawai‘i and worldwide require that we take a more holistic approach for better management and conservation of marine ecosystems. Ecosystem management has gained growing support in recent years (Pikitch et al. 2004). This approach relies on an improved understanding of ecological structure and ecosystem processes and function, especially in complex ecosystems such as coral reefs.

To inventory ecosystems, it is necessary to determine the presence and distribution of resources (both living and non-living features). Ideally, inventories should also include information on species composition, relative abundance, and spatial distribution of organisms and their habitat affinities. Coupling the distribution of habitats and species habitat affinities using GIS technology enables the elucidation of species habitat utilization patterns for a single species and/or assemblages of animals. Integrating spatial data into the biological sampling design can help identify and quantify spatial dependencies in habitat utilization by marine vertebrates. This integrated approach is useful in quantitatively defining resource abundance, associations, habitat requirements (especially, essential habitats), and defining biologically relevant boundaries of marine protected areas. The combination of marine habitat mapping and spatially-explicit biological sampling has provided a unique opportunity for management agencies and collaborators to develop monitoring programs and protocols.

Information on marine resources within and adjacent to Hawaiian national parks has been provided in numerous investigations (e.g. Godwin and Bolick 2006). However, data specific to marine vertebrates are limited and vary greatly among locations. This inventory project was developed to provide quantitative data on marine vertebrates at four national parks in Hawai‘i.

The marine vertebrate inventory project in the four designated NPS units in Hawai‘i had a broader scope than an inventory list of species. The goals and objectives included characterization of the marine vertebrate assemblages and the habitats that they utilize. Results will enable more informed management decisions and the development of sound monitoring protocols of identified vital signs and significant resources.

The following NPS units (Figure 1) were included in this investigation:

Island of Moloka‘i:
Kalaupapa National Historical Park (KALA): waters within the park.

Island of Hawai‘i :
Pu‘ukoholā Heiau National Historic Site (PUHE): waters adjacent to the park
Kaloko-Honokōhau National Historical Park (KAHO): waters within the park.
Pu‘uhonua o Hōnaunau National Historical Park (PUHO): waters adjacent to the park

The goals and objectives of this project were to:

1. Develop an inventory list of all marine vertebrate species that occur or potentially occur in waters within/adjacent to designated NPS units.
2. Spatially characterize the distribution, species composition, and relative abundance of marine vertebrates, especially reef fishes.
3. Relate this information to *in-situ* data collected on associated habitat parameters.
4. Establish the knowledge base necessary for enacting management decisions in a spatial setting and to establish the efficacy of those management decisions.
5. Work with the National Coral Reef Ecosystem Monitoring Program to develop data collection standards and easily implemented methodologies for transference to other agencies and to work toward standardizing data collection throughout the US states and territories.

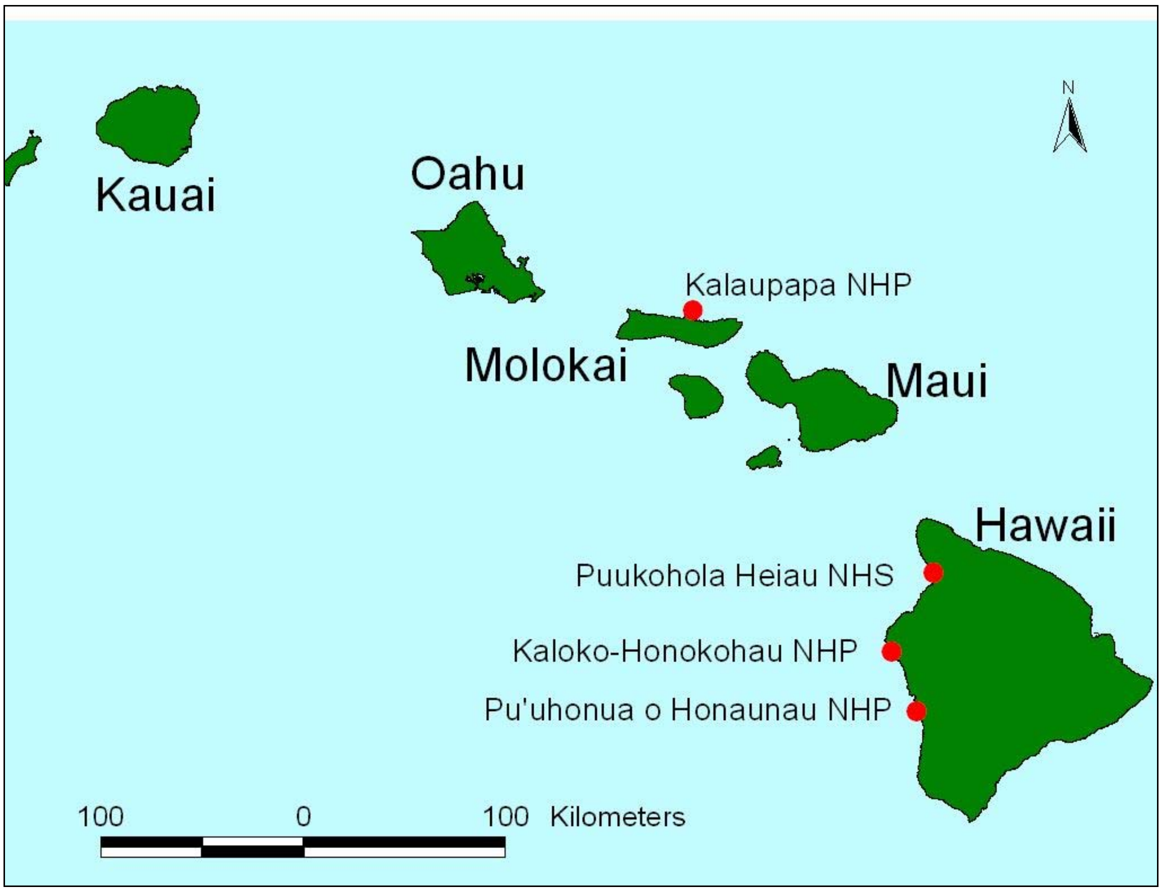


Figure 1. Location of the four national parks sampled in Hawai'i during the marine vertebrate inventory in 2005.

METHODS

Sampling design and methodology

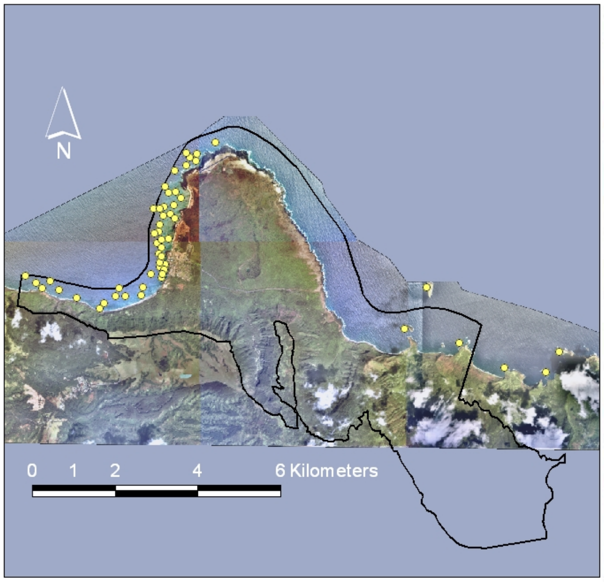
Most of the sampling effort for this investigation was allocated to marine fishes, since they account for the greatest proportion of marine vertebrate species found within these four national parks and are routinely extracted from park waters. We used non-destructive methods, recognizing that a large number of reef fishes are cryptic and cannot be sampled without the use of ichthyocides. Ichthyocides, however, are not permitted by the State of Hawai‘i, and therefore were not utilized in this study. Thus, the primary methods used were visual sampling methods adopted by NPS and the National Oceanic and Atmospheric Administration (NOAA) (Friedlander et al. 2006). Project sampling was conducted from January through August, 2005. No specimens were collected, so no voucher specimens were accessioned. In addition to observations made during the project, NPS publications and field notes were reviewed for marine reptile and marine mammal sightings to create a species list. Observations of activity were summarized for this report.

Sampling locations-site/habitat selection

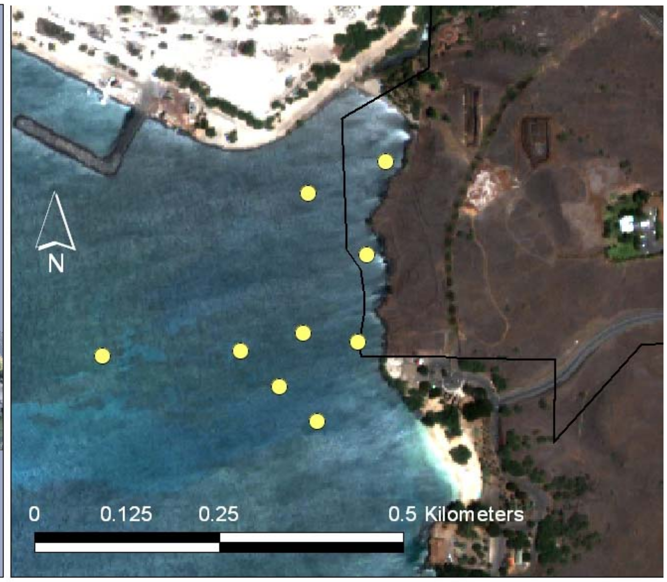
Within the four designated NPS units, sampling sites were selected based on discussions with NPS staff and use of a stratified random design with available benthic habitat maps. The National Oceanic and Atmospheric Administration produced benthic habitat maps for near-shore waters (to 25 meters depth) of a large portion of the main Hawaiian Islands, including three of the four NPS units included in the inventory project (KALA has not been mapped). These GIS-based benthic habitat maps were characterized by a high degree of spatial and thematic accuracy. The hierarchical spatial structure underlying the habitat classifications were explicitly designed to include ecologically-relevant locational (forereef, reef flat, lagoon, etc.) and typological (aggregated reef, colonized pavement, etc.) strata. This approach created an analytical construct within which nuances of community structure, such as resource distribution, abundance, and habitat utilization could be tested and resolved.

The Geographic Information System (GIS) habitat maps created by NOAA's Biogeography Program have been reinterpreted at a finer scale by NPS and the US Geological Survey (USGS) in Hawai‘i. All available datasets were used to select random sampling sites by habitat type, using established stratified random sampling protocols (Christensen et al. 2003; Friedlander et al. 2006) and GIS software (ArcGIS 8/9 and ArcView 3.3) to ensure complete coverage of each of the four NPS units (Figure 2 A-D). Random points were assigned in major substrate types (e.g., colonized hard bottom [>10% coral cover], uncolonized hard bottom [<10% coral cover], and unconsolidated sediment [sand]). Location points in latitude and longitude or Universal Transverse Mercator (UTM) coordinates were downloaded into a Global Positioning System (GPS) unit for use in the field. Transect sites were further delineated by habitat (e.g., aggregated reef, scattered coral, pavement, volcanic rock/boulder, mud, sand) during post processing. This was a collapsible hierarchy with the major substrate types consisting of one or more habitat categories. For example, within a park colonized hard bottom could contain aggregated reef, scattered coral, pavement, and volcanic rock/boulder habitats.

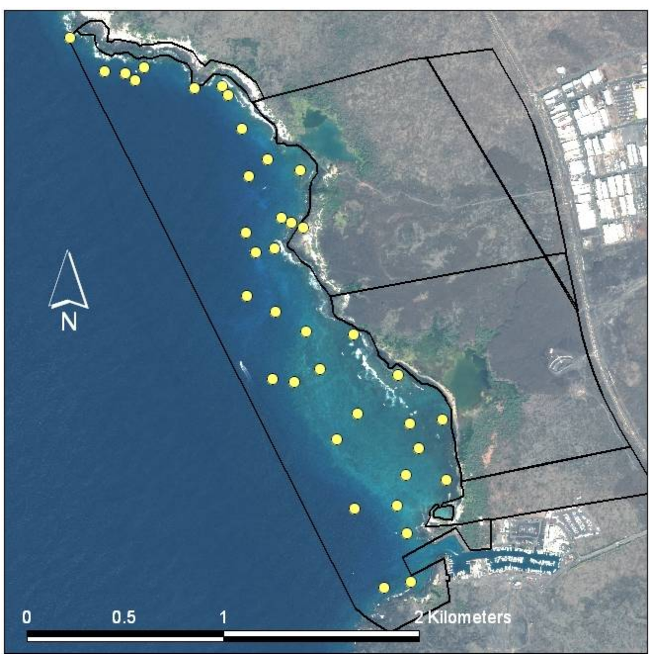
A. Kalaupapa National Historical Park (KALA), Island of Moloka‘i



B. Pu‘ukoholā Heiau National Historic Site (PUHE), Island of Hawai‘i



C. Kaloko-Honokōhau National Historical Park (KAHO), Island of Hawai‘i



D. Pu`uhonua o Hōnaunau National Historical Park (PUHO), Island of Hawai‘i

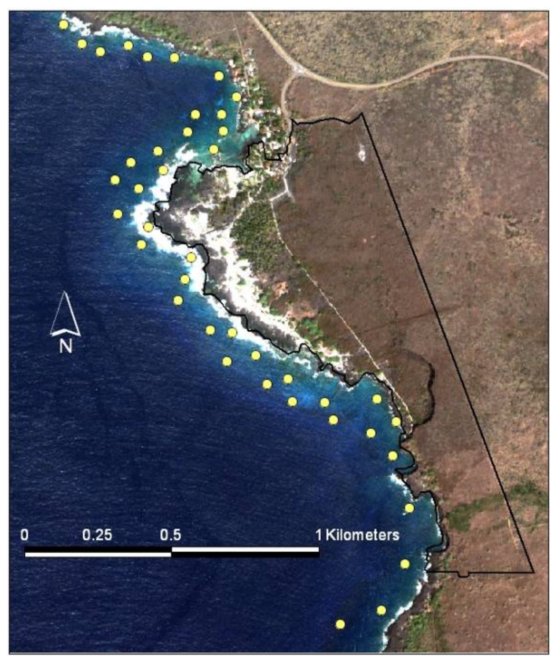


Figure 2. Locations of marine fish subtidal sampling stations in the four national parks in Hawai‘i sampled during 2005. Black lines denote park boundaries.

A field team consisting of three samplers navigated to waypoints using a GPS unit. Direction of each transect was determined randomly along the isobath of that point except in cases where that direction traversed multiple habitats. In those situations, transects were run within a habitat polygon along a similar isobath strata.

Marine fish sampling methodology

Three different zones were identified for marine fish sampling: subtidal, shoreline, and tidal pools. Different sampling methods were used for each zone.

Reef fish subtidal sampling

Sampling in subtidal habitats extended from the mean low water line to 30 m. At each random point (station), reef fishes were sampled on Scuba using the visual belt transect survey method (Brock 1954; Brock 1982). The sampler swam a 25 m x 5 m transect at a constant speed (~ 15 min/transect) and enumerated all fishes, identified to the lowest possible taxon, visible within 2.5 m to either side of the centerline (125 m^2 transect area). The sampler visualized out to the end of the transect and enumerated all individuals that were potentially leaving the census area. In this manner, we partially accounted for the behavior that targeted species acquire in areas that are frequented by spearfishers. Following transect completion, the sampler collected presence/absence data of species in the transect area that were not observed in the transect for a 5-10 min period (these data only listed species without abundance estimates). The sampling unit was a single pass along one transect surveyed by one sampler. Nomenclature followed Randall (1996). Total length (TL) of fish was estimated to the nearest centimeter. Length estimates of fishes from visual censuses were converted to weight using the following length-weight conversion: $W = aSL^b$ - the parameters a and b are constants for the allometric growth equation where SL is standard length in mm and W is weight in grams.

Shoreline fish sampling

Shoreline sampling was conducted by snorkeling at KAHO and PUHO, starting at the mean low tide level and extending seaward 5-10 m. The shoreline habitat at most sites was a stepped lava bench which rapidly dropped to 3-5 m. A few sites consisted of gentle beach or rock pavement that sloped gradually into shallow water. KALA and PUHE were not sampled using this method.

Haphazard sampling along the shoreline was conducted using the Roving Diver Fish Count method (Davis et al. 1997). During Roving Diver Fish Counts, paired samplers recorded all fish species observed. This method produced two indices of fish abundance: one scaled from 0 to 10, and an actual estimated count expressed in categories (single = 1, few = 2-10, common = 11-100, and many = >100). A modification of this method was employed since sampling was conducted along irregular shoreline benches. Instead of sampling along both sides of a transect, fishes were recorded along a section of shoreline.

Tidal Pool fish sampling

Tidal pool sampling was conducted using qualitative methods. Pools were selected based on discussions with NPS staff and shoreline surveys. A combination of visual observations and small net collection were used to identify species. All specimens were returned following identification.

Benthic survey techniques

Coral species richness and percent coverage were examined using the *in-situ* planar point intercept quadrat method (Reed 1980). Each 25-m fish transect was stratified into 5 x 5 m segments with one quadrat randomly placed within each segment for a total of five subsamples. The quadrat grid was one square meter in area and consisted of one inch PVC tubing fitted with nylon line spaced 10 centimeters apart to form a square grid with 81 intersections. A subset of 25 randomly selected intersections were marked and used for substrate identification. The rationale for the subset was that 25 points sufficiently represented the habitat with acceptable error and optimized sampling time (Friedlander et al. 2006).

Each intersection was identified using substrate categories of sand, coralline algae, turf algae, macroalgae, *Halimeda spp.,* and coral. Coral and macroinvertebrates were identified to species using Veron (2000) and Hoover (2003), respectively. The macroinvertebrates category incorporated echinoderms and other large invertebrates (e.g., zooanthids, octocorals) that occupied significant portions of the substrate. Macroinvertebrates were also included in the results for comparative purposes, but the methodology limited conclusions about distribution and abundance for this group of organisms. Limitations of *in-situ* methodology precluded taxonomic resolution of algae to the species level so algae were identified to genera using Littler and Littler (2003). Percent cover values for each substrate category and coral species were derived by dividing the number of occupied points by the total number of intersections (25) within each quadrat.

To measure reef rugosity or surface relief, a chain of small links (1.3 cm per link) was draped along the full length of the centerline of each transect (Risk 1972). Care was taken to ensure that the chain followed the contour of all natural fixed surfaces directly below the transect centerline. The ratio of distance along the reef surface contour to linear horizontal distance gave an index of spatial relief or rugosity.

Data Analysis

Fish biomass was ln(x+1) transformed prior to statistical analysis to conform to the assumptions of normality and homogeneity of variance (Zar 1999). Species diversity was calculated from the Shannon-Weaver Diversity Index (Ludwig and Reynolds 1988): H’=S (pi ln pi), where pi is the proportion of all individuals counted that were of species i.

Comparisons of fish species richness, density, biomass, and diversity among management strata and habitat types were conducted using one-way Analysis of Variance (ANOVA).

Unplanned comparisons between pairs were examined using the Tukey-Kramer HSD (honestly significant difference) test for ANOVA ($\alpha = 0.05$).

Non-metric multidimensional scaling (MDS) using PRIMER v5 software (Clarke and Gorley 2001) was used to explore the relationships among fish assemblages and among hardbottom benthic assemblages at the park level. Comparisons of fish density and biomass among parks were subsequently tested using a permutation-based hypothesis testing Analysis of Similarities (ANOSIM in PRIMER 5.0; Clarke and Gorley 2001; Clarke and Warwick 2001). In the one-way ANOSIM, density and biomass were the dependent variables and park was treated as an independent factor. An overall R statistic was generated that was on a scale from 0 or negative value (identical assemblages) to 1 (dissimilar assemblages). In addition, multiple pairwise comparisons for each park generated R statistics indicating the similarity of the park assemblage combinations and the probability (p) that the different assemblages came from the same distribution.

Species dominance and accumulation curves for fish density and biomass were generated for each park using PRIMER v5. Fish biomass at the family level was examined for each park as well as the biomass contribution of introduced species. Finally, spatial distribution bubble plots for each of the fish assemblage characteristics were generated using ArcMap 9.2.

The ten dominant benthic species/substrates, in terms of percent cover, were compiled for each park. Percent cover data were arcsin-square root transformed prior to statistical analysis to meet the assumptions of normality (Zar 1999). Substrate cover within each park was statistically examined using a General Linear Model (GLM) nested ANOVA with percent cover as the dependent variable and substrate type (7 levels; coralline algae, coral, macroinvertebrates, macroalgae, plant sand/silt, and turf algae) nested within park (4 levels; KAHO, KALA, PUHE, and PUHO) as factors. Post-hoc multiple comparisons among substrate types used Tukey's unequal HSD. A GLM nested ANOVA was used to compare focal benthic taxa (i.e. coral and macroalgae) within each park. Post-hoc comparisons were conducted using Tukey's HSD test.

For the benthic analysis, percent cover for the different taxa was averaged for each transect within a park. Presentation of benthic results was simplified to focus on the statistical analysis of the fish assemblage characteristics. Therefore, only mean values of benthic cover were reported in the tables with error estimates shown in the figures. In addition, ANOVA and multiple comparison tables were excluded but the results of the statistical analyses were graphically presented in the figures.

Mean and standard deviation for rugosity were tabulated by habitat type for each park.

RESULTS

Marine fishes

A total of 178 marine fish species were observed in the marine waters adjacent to all four parks (Appendix A). A total of 48 endemic species (27% of the total) were observed during this investigation. The numbers of marine fish species observed within each park and among sampling zones are presented in Table 1, with the number of quantitative samples made within in each park by zone presented in Table 2. The greatest number of species was observed in KAHO, followed by PUHO and KALA. Very few species were recorded from PUHE.

Table 1. *Total number of marine fish species observed within each park and for each sampling zone per park, 2005. Species numbers provided under 'All investigations' include those observed by Doty 1969 , Cheney et al., 1977, Ludwig et al. 1980, and Tissot 1998.*

Park Totals	KALA		PUHE	KAHO			PUHO		
Present investigation	133		57	164			151		
All investigations	142		70	199			168		
Zone Totals	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
Present investigation	131	13	57	109	161	19	107	131	33
All investigations	140	13	70	109	189	19	107	148	33

Table 2. *Number of quantitative samples taken within each park by sampling zone.*
x – denotes qualitative samples

Sampling Zone	KALA	PUHE	KAHO	PUHO
Subtidal	53	9	38	41
Shoreline			24	15
Tidepool	x		x	x

Subtidal sampling

Average density and biomass for all species observed in subtidal sampling are presented in Appendix B. Characteristics (species richness, biomass, density and diversity) of the marine fish assemblages were similar among three of the four parks, with PUHE having much lower values than the other parks (Table 3). Generally, the assemblage characteristic values were larger for KALA than for other parks. KALA and PUHO had similar values for species richness, although KALA had a significantly greater value than KAHO and PUHE (Figure 3). Average values for fish density were not significantly different among KALA, PUHO, and KAHO, although PUHE had a significantly lower value (Figure 4). Biomass was much larger for KALA than the other three parks, which were statistically similar (Figure 4). The greater biomass value for KALA was due to higher densities of larger fish species (e.g., goatfishes - *Mulloidichthys vanicolensis, Parupeneus multifasciatus*; parrotfishes - *Scarus dubius, S. psittacus*; surgeonfishes - *Naso hexacanthus, N. unicornis*) than for the other three parks (Appendix B). KALA had a significantly greater average diversity than did KAHO and PUHE (Figure 6).

Non-metric multidimensional scaling (MDS) provided graphical views of the relationship among parks for fish density and biomass. For both density and biomass, KALA and PUHE clustered separately from KAHO and PUHO (Figures 7 & 8). The latter two parks generally clustered together for both fish density and biomass in comparison to KALA and PUHE which clustered on opposite ends of the ordination space. Fish assemblages were statistically similar at KAHO and PUHO compared to PUHE and PUHO in terms of species density (Table 4). This pattern among parks was also observed for fish biomass (Table 5).

Species dominance curves differed between fish density and biomass. For both parameters, ten species accounted for more than 90% of the total fish density and biomass of samples taken at PUHE (Figures 9 & 10). Ten species accounted for less than 60% of total fish density at KALA and more that 70% at PUHO, with KAHO in between these values. Results for fish biomass were similar for KALA, KAHO, and PUHO, with ten species accounting for approximately 60% of total biomass.

Species accumulation curves were very similar for KAHO and PUHO, but species accumulation were greater for KALA samples (Figure 11). With 20 samples (belt transects), approximately 80 species were observed for KAHO and PUHO (nearly 90% of total observed) and approximately 100 species for KALA (approx. 83% of total observed).

Generally, marine fish assemblage characteristics had larger values in coral reef (colonized) hardbottom substrate than did uncolonized hardbottom (Table 3). Interestingly, colonized volcanic rock (with > 10% coral cover) usually had greater assemblage characteristic values than did aggregated reef and other habitat types. An exception was high density and biomass values at PUHO for aggregated reef habitat. Sand had low values for all assemblage characteristics.

Several important differences emerged among parks at the family level (Appendix C). KALA had greater densities and biomass of several dominant families, including squirrelfishes/solderfishes (Holocentridae), jacks/trevallies (Carangidae), goatfishes (Mullidae), damselfishes (Pomacentridae), and wrasses (Labridae). In comparison, KAHO and PUHO had larger densities of butterflyfishes (Chaetodontidae) and surgeonfishes (Acanthuridae), although KALA had a larger biomass of surgeonfishes due to the greater numbers of large fishes mentioned above. Many of these differences were due to habitat differences, but probably also to differences in fishing pressure. The subtidal environments in KALA, past the inshore basalt benches, are dominated by very large boulders that provide excellent habitat relief for fishes.

The ranks of numerically dominant species were very similar among three of the four parks. PUHE had not only lower abundances but different species composition. The blackfin chromis (*Chromis vanderbilti*) was the most abundant fish surveyed in KALA, KAHO, and PUHO, but subsequent ranks in density greatly varied (Appendix B). The endemic saddle wrasse, (*Thalassoma duperrey*) was one of the dominant three species for all three of these parks, along with one of three surgeonfish species (KALA—*Acanthurus leucopareius*; KAHO—*Acanthurus nigrofuscus*; PUHO—*Zebrasoma flavescens*). Only three additional endemic species were commonly observed within these parks (multiband butterflyfish, *Chaetodon multicinctus*; Hawaiian sergeant, *Abudefduf abdominalis*; and belted wrasse, *Stethojulis balteata*).

Biomass was generally dominated by surgeonfishes (Acanthuridae) at KALA, KAHO, and PUHO. As mentioned, KALA had the largest fishes observed, and harvested species, such as the Hawaiian hogfish (*Bodianus bilunulatus*), were among the dominant species in biomass (Appendix B). Introduced species, ta'ape (bluestripe snapper, *Lutjanus kasmira*) and roi (peacock grouper, *Cephalopholis argus*), were among the dominant fishes in biomass at KALA, KAHO, and PUHO, with ta'ape being the dominant species in biomass at KAHO. Juvenile parrotfishes dominated biomass and density at PUHE, although the introduced species to'au (blacktail snapper, *L. fulvus*) ranked sixth in biomass at that park.

***Table 3**. Average species richness (number of species 125 m^{-2}), density (number 125 m^{-2}), biomass (mt ha^{-1}), and diversity (H') per transect for marine fishes among major substrate categories (in gray) and habitat types for each park. Standard deviations are presented in parentheses; sample sizes are presented under N. Blank values denote that category was not represented by transects sampled in that park.*

A. Species Richness

	KALA		N	PUHE		N	KAHO		N	PUHO		N
Coral reef hardbottom	22.8	(6.2)	31	8.5	(4.3)	6	19.6	(6.3)	30	19.9	(4.5)	40
Aggregated reef				10.0		1	19.5	(7.4)	4	19.9	(3.0)	12
Scattered coral				6.3	(2.1)	4						
Pavement	17.0	(3.7)	4	16.0		1	15.2	(6.0)	10	18.3	(2.9)	6
Volcanic rock	23.7	(6.1)	27				22.4	(4.6)	16	20.4	(5.4)	22
Uncolonized reef hardbottom	23.9	(8.0)	15				13.5	(4.2)	6			
Pavement	16.7	(10.0)	3				11.0	(2.2)	4			
Volcanic rock	25.7	(6.8)	12				18.5	(0.7)	2			
Unconsolidated	0.7	(0.5)	7	1.0		3	4.0	(4.2)	2	4.0		1
Mud				1		2						
Sand	0.7	(0.5)	7	1		1	4.0	(4.2)	2	4		1
Overall	20.2	(9.9)	53	6.0	(5.1)	9	17.8	(7.0)	38	19.5	(5.1)	41

B. Density

	KALA		N	PUHE		N	KAHO		N	PUHO		N
Coral reef hardbottom	10.3	(4.5)	31	6.3	(6.1)	6	8.1	(4.3)	30	9.2	(5.0)	40
Aggregated reef				11.0		1	8.2	(2.8)	4	10.6	(6.6)	12
Scattered coral				2.8	(3.2)	4						
Pavement	12.1	(4.7)	4	15.5		1	3.3	(5.2)	10	9.3	(4.8)	6
Volcanic rock	10.1	(4.6)	27				9.9	(4.3)	16	8.4	(4.0)	22
Uncolonized reef hardbottom	9.2	(3.8)	15				6.1	(2.1)	6			
Pavement	7.0	(4.5)	3			1	5.3	(2.1)	4			
Volcanic rock	9.7	(3.6)	12				7.9	(0.5)	2			
Unconsolidated	0.1	(0.1)	7	0.2	(0.3)	3	0.4	(0.5)	2	0.4		1
Mud				0.1		2						
Sand	0.1	(0.1)	7	0.6		1	0.4	(0.5)	2	0.4		1
Overall	8.6	(5.2)	53	4.3	(5.7)	9	7.4	(4.3)	38	9.0	(5.1)	41

C. Biomass

	KALA		N	PUHE		N	KAHO		N	PUHO		N
Coral reef hardbottom	1.067	(0.873)	31	0.391	(0.440)	6	0.539	(0.478)	30	0.565	(0.348)	40
Aggregated reef				0.503		1	0.428	(0.223)	4	0.758	(0.469)	12
Scattered coral				0.172	(0.247)	4						
Pavement	0.488	(0.398)	4	0.152		1	0.373	(0.253)	10	0.336	(0.064)	6
Volcanic rock	1.153	(0.895)	27				0.670	(0.595)	16	0.523	(0.266)	22
Uncolonized reef hardbottom	0.972	(0.593)	15				0.490	(0.542)	6			
Pavement	0.363	(0.220)	3				0.166	(0.074)	4			
Volcanic rock	1.125	(0.559)	12				1.139	(0.437)	2			
Unconsolidated	0.032	(0.068)	7	0.002	(0.004)	3	0.047	(0.061)	2	0.030		1
Mud				0.003	(0.005)	2						
Sand	0.032	(0.068)	7	<0.001		1	0.047	(0.061)	2			1
Overall	0.920	(0.807)	53	0.261	(0.398)	9	0.505	(0.481)	38	0.552	(0.354)	41

D. Diversity

	KALA		N	PUHE		N	KAHO		N	PUHO		N
Coral reef hardbottom	2.34	(0.45)	31	1.39	(0.17)	6	2.14	(0.39)	30	2.18	(0.37)	40
Aggregated reef				1.32		1	2.05	(0.36)	4	2.15	(0.25)	12
Scattered coral				1.34	(0.15)	4						
Pavement	1.93	(0.47)	4	1.66		1	2.07	(0.41)	10	1.91	(0.44)	6
Volcanic rock	2.41	(0.43)	27				2.24	(0.38)	16	2.28	(0.39)	22
Uncolonized reef hardbottom	2.45	(0.53)	15				2.07	(0.23)	6			
Pavement	2.09	(0.52)	3				1.99	(0.25)	4			
Volcanic rock	2.54	(0.52)	12				2.23	(0.08)	2			
Unconsolidated	<0.01	(0.00)	7	<0.01		3	0.94	(1.33)	2	1.33		1
Mud						2						
Sand	<0.01	(0.00)	7			1	0.94	(1.33)	2	1.33		1
Overall	2.06	(0.93)	53	0.93	(0.71)	9	2.08	(0.50)	38	2.16	(0.39)	41

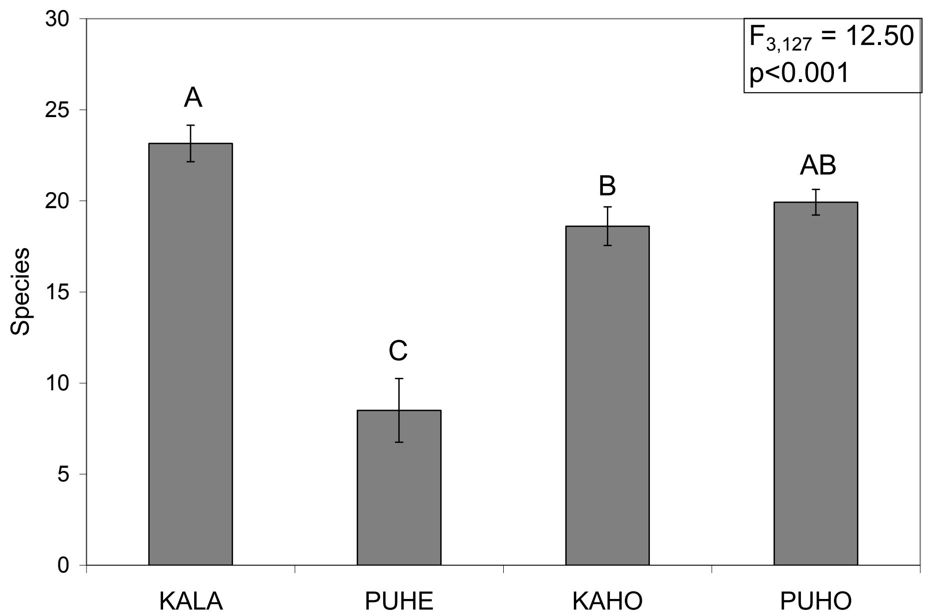


Figure 3. Species richness of fishes observed (mean number 125 $m^{-2} \pm$ SE) among the four national parks from subtidal samples on hard bottom substrates in 2005. Results of ANOVA are presented; letters above bars are multiple comparison test results, with the same letter denoting statistically similar means at $\alpha = 0.05$.

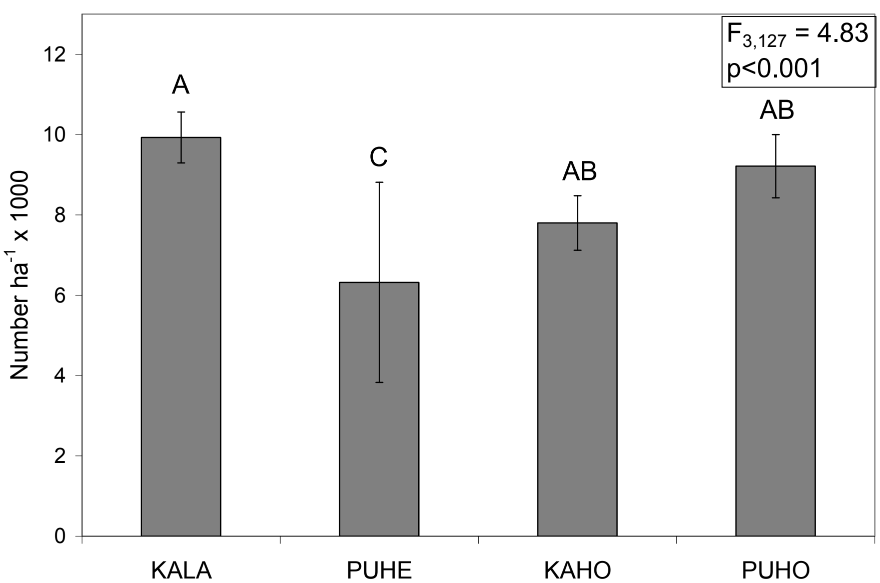


Figure 4. Density of fishes observed (mean number $ha^{-1} \times 1000 \pm$ SE) among the four national parks from subtidal samples on hard bottom substrates in 2005. Results of ANOVA are presented (number of fishes ln(x+1) transformed); letters above bars are multiple comparison test results, with the same letter denoting statistically similar means at $\alpha = 0.05$.

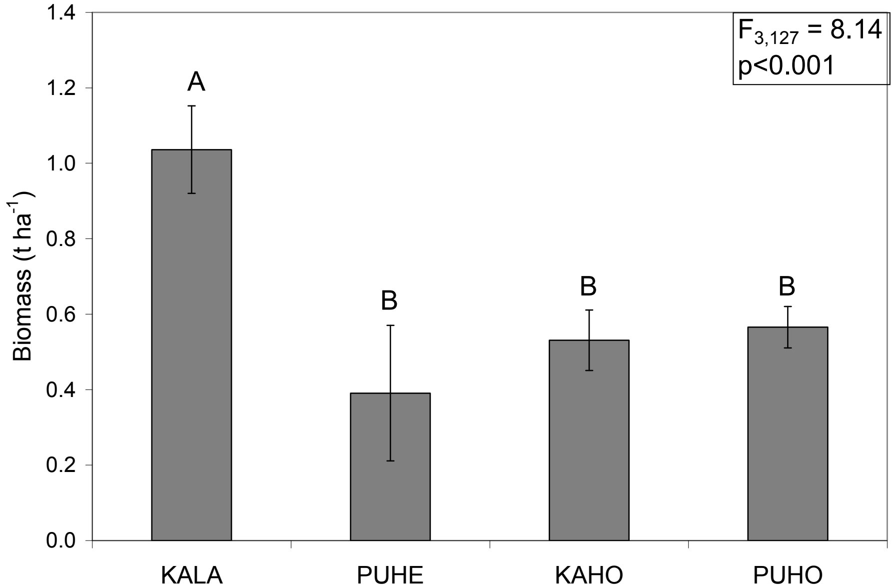


Figure 5. Biomass of fishes observed (mean metric tons $ha^{-1} \pm$ SE) among the four national parks from subtidal samples on hard bottom substrates in 2005. Results of ANOVA are presented (biomass ln(x+1) transformed); letters above bars are multiple comparison test results, with the same letter denoting statistically similar means at α = 0.05.

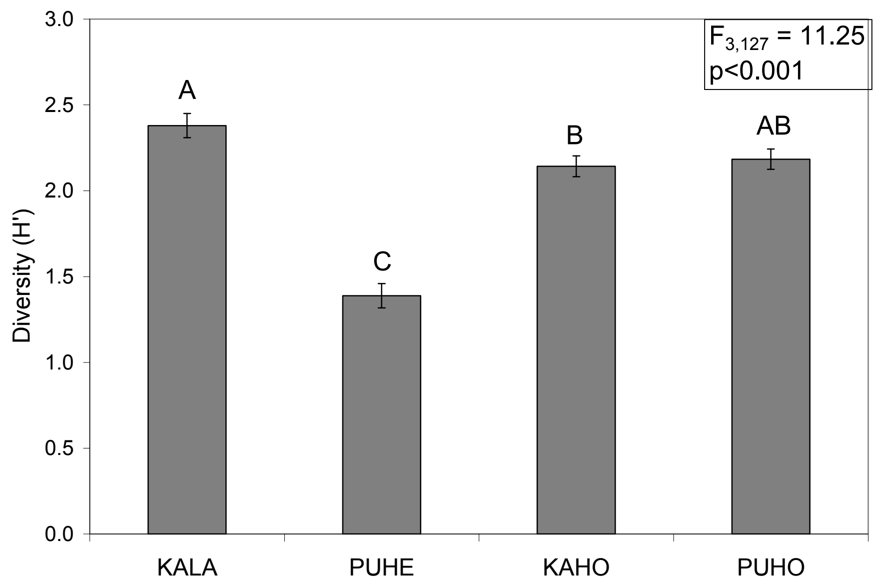


Figure 6. Diversity of fishes observed (mean H' ± SE) among the four national parks from subtidal samples on hard bottom substrates in 2005. Results of ANOVA are presented; letters above bars are multiple comparison test results, with the same letter denoting statistically similar means at α = 0.05.

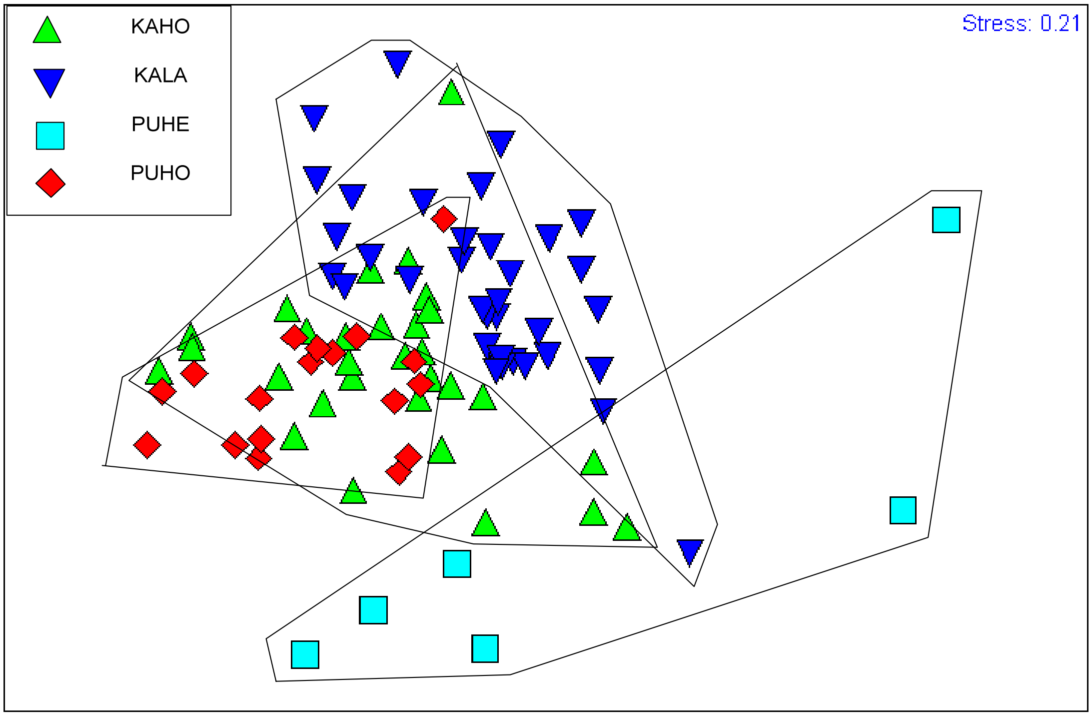


Figure 7. Multidimensional scaling (MDS) plot based on fish species density (number ha^{-1} x 1000) among four national parks sampled in 2005.

Table 4. Pair-wise comparisons of fish assemblages among parks based on density using analysis of similarities (ANOSIM). Scale of R values is from 0 or negative values (identical faunas) to 1 (dissimilar faunas).

Park comparisons	R	p	Similarity
PUHE & PUHO	0.877	0.001	Least
KALA & PUHE	0.872	0.001	
KAHO & PUHE	0.764	0.001	
KALA & PUHO	0.440	0.001	
KAHO & KALA	0.223	0.001	
KAHO & PUHO	0.043	0.162	Most

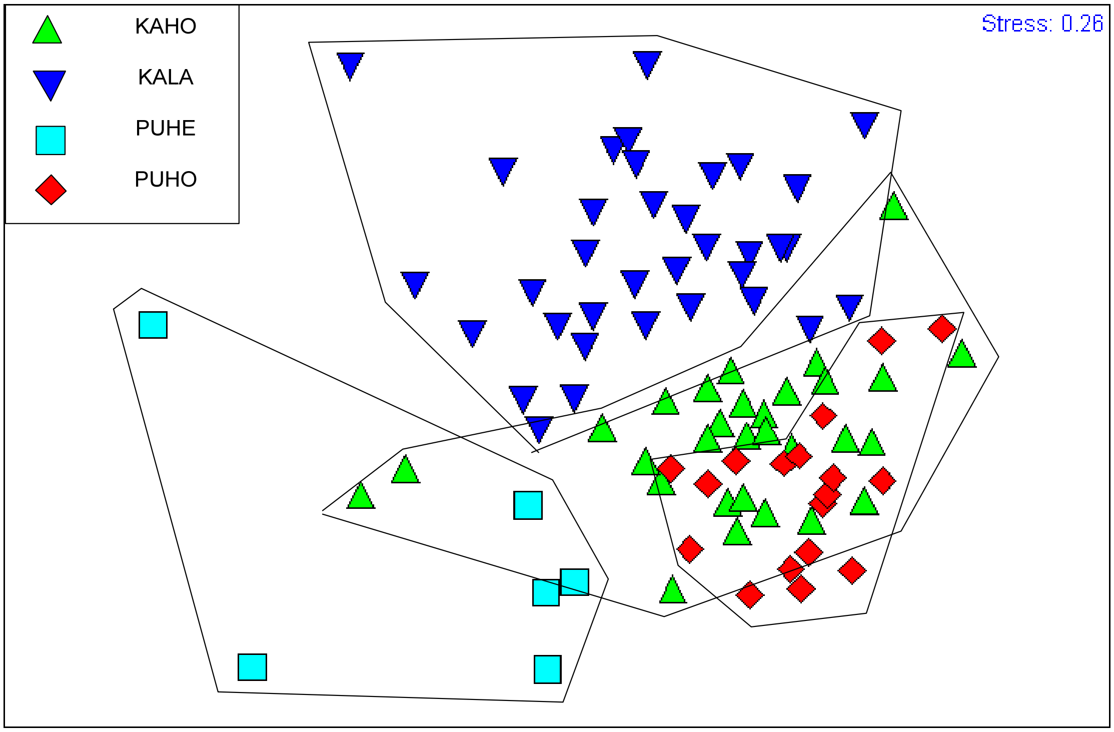


Figure 8. Multidimensional scaling (MDS) plot based on fish species biomass (metric tons ha^{-1}) among four national parks sampled in 2005.

Table 5. *Pair-wise comparisons of fish assemblages among parks based on biomass using analysis of similarities (ANOSIM). Scale of R values is from 0 or negative values (identical faunas) to 1 (dissimilar faunas).*

Park comparisons	R	p	Similarity
PUHE & PUHO	0.798	0.001	Least
PUHE & KALA	0.754	0.001	
KAHO & PUHE	0.688	0.001	
PUHO & KALA	0.490	0.001	
KAHO & KALA	0.346	0.001	
KAHO & PUHO	0.033	0.225	Most

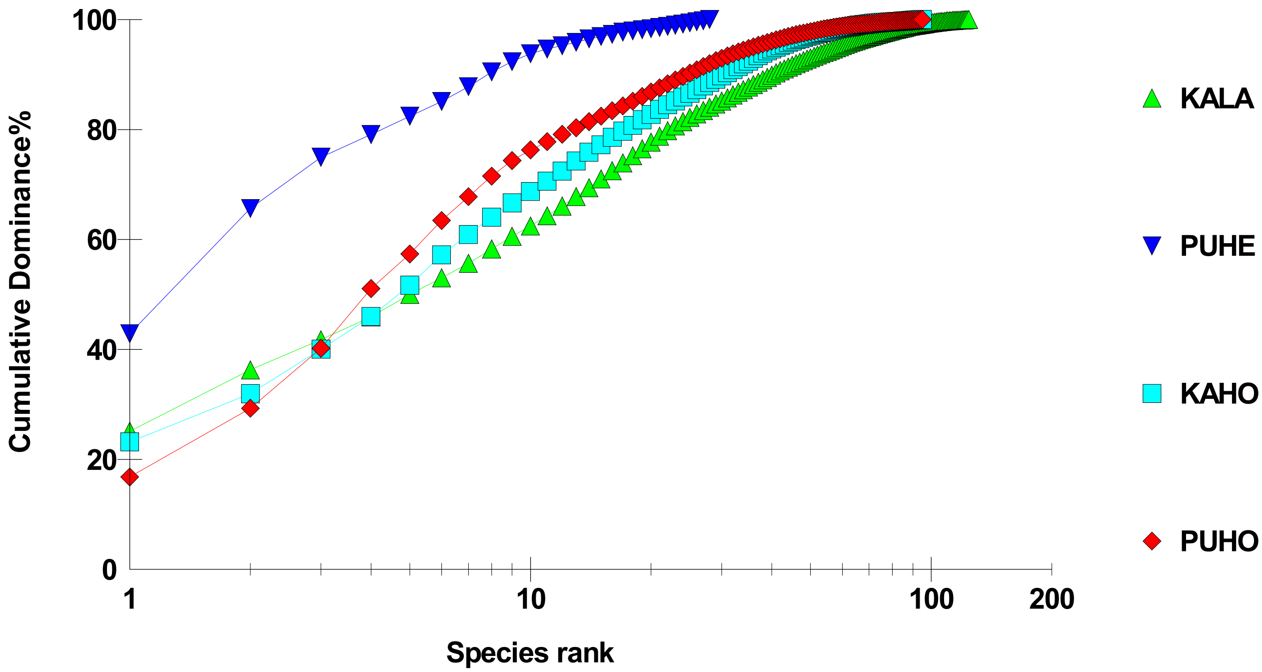


Figure 9. Comparison of species dominance curves for fish abundance among four national parks sampled in 2005.

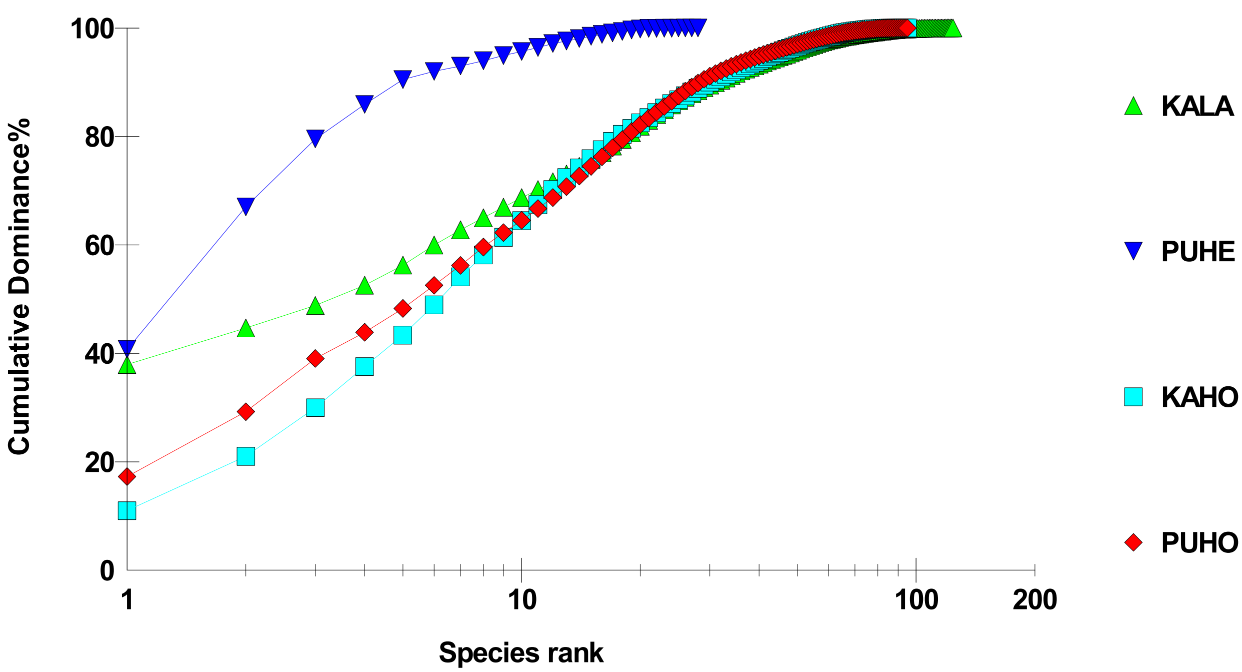


Figure 10. Comparison of species dominance curves for fish biomass among four national parks sampled in 2005.

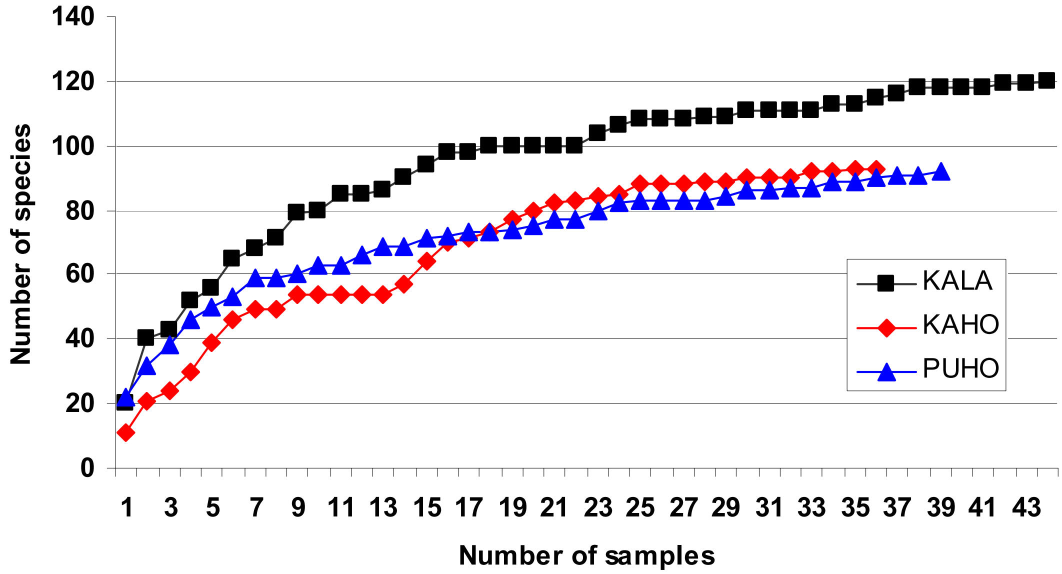


Figure 11. Comparison of fish species accumulation curves among three national parks sampled in 2005. PUHE was not included in this analysis due to small sample size.

Spatial patterns of fish assemblage characteristics within parks

Fish assemblage characteristics (species richness, density, biomass, and diversity) were plotted as proportional bubbles and overlaid on orthorectified aerial photos for each park and adjacent locations (Figures 12 – 15). Classification for characteristic was based on quantiles.

KALA

Species richness tended to be higher on the colonized hard bottom habitats and lowest in the sand and reef flat habitats (Figure 12 A-D). Density and diversity showed no clear spatial pattern other than low values observed on sand and low-relief habitats. Biomass was highest at the points of land and along the leeward side, particularly towards the north end.

PUHE

Fish assemblage characteristics were low overall at PUHE with the highest value observed at the most seaward sampling point (Figure 13 A-D). This pattern was most likely due to better water quality and greater habitat complexity/quality compared with the sampling locations farther inside the bay.

KAHO

At KAHO, species richness and biomass were generally higher at the points of land and in deeper water (Figure 14 A-D). Density tended to be higher in the northern portion of the park while diversity showed no apparent pattern.

PUHO

Values for most fish assemblage characteristics at PUHO were intermediate to those at the other three parks surveyed (Figure 15 A-D). At PUHO, there were no apparent patterns in assemblage characteristics although biomass tended to be greater in the northern and southern portions of the park.

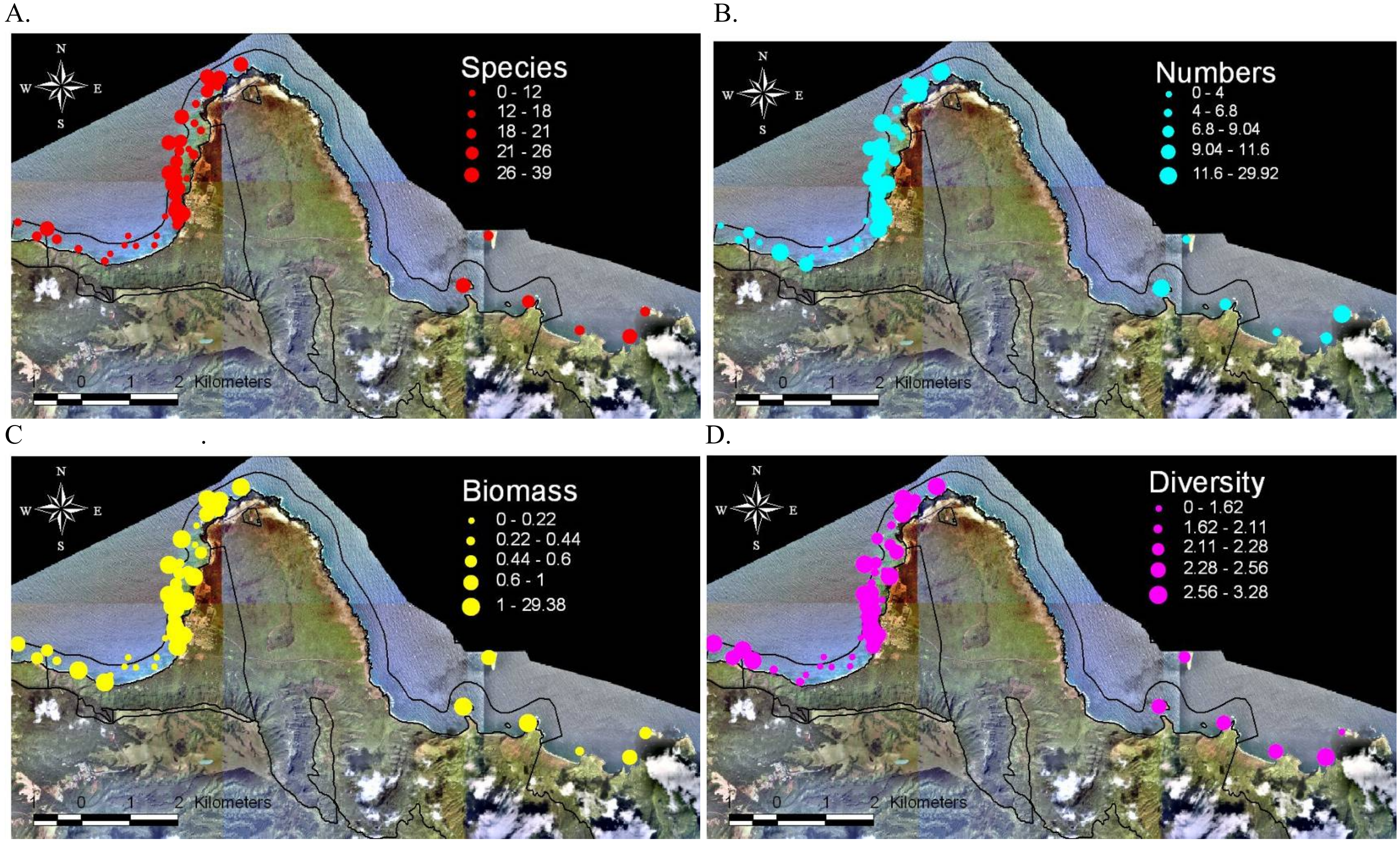


Figure 12. Spatial distribution of A. fish species richness (no. of species 125 m^{-2}), B. density (no. of individuals ha^{-1} x 1000), C. biomass (mt ha^{-1}), and D. diversity (H') among sampling locations at KALA.

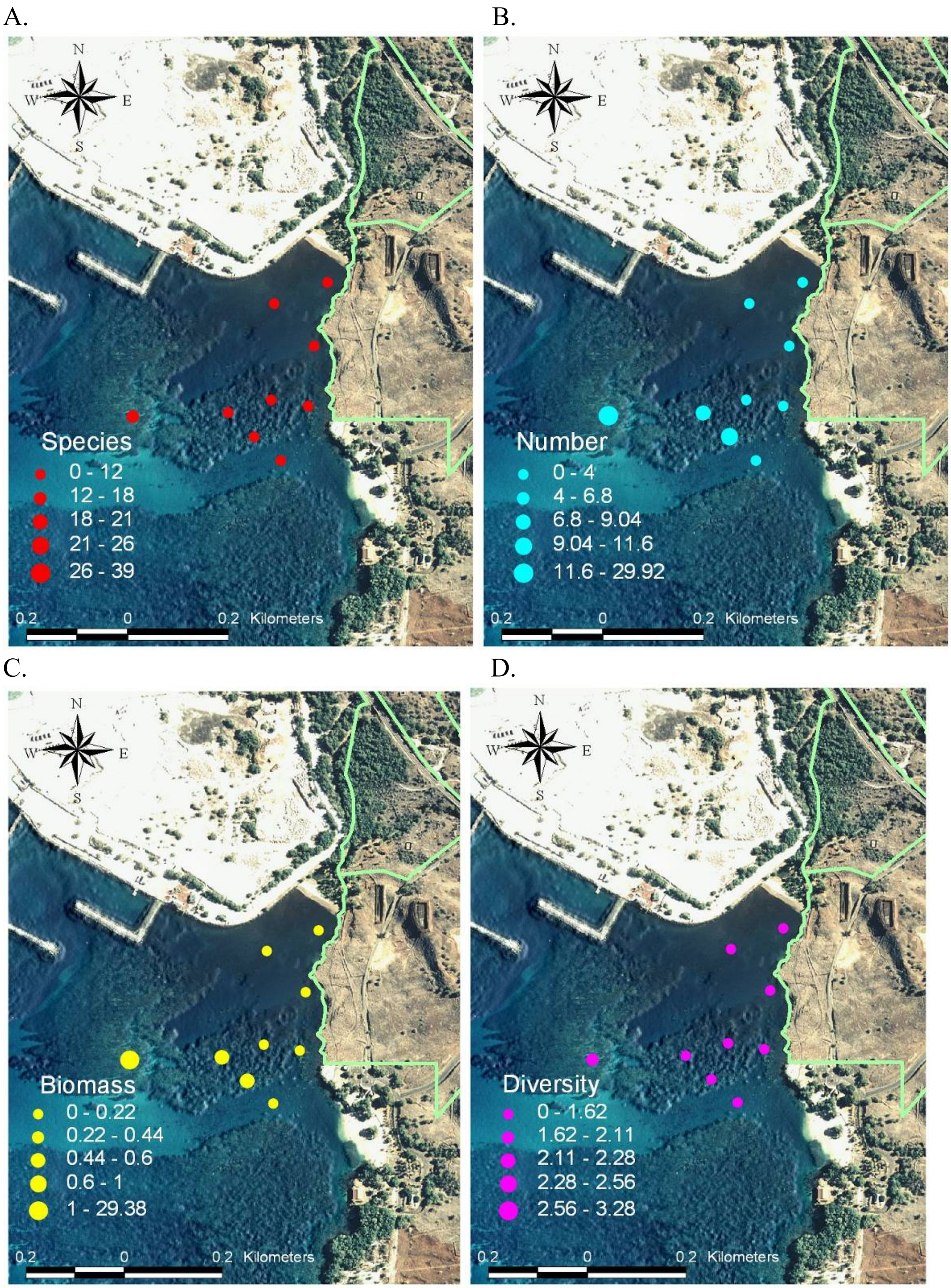


Figure 13. Spatial distribution of A. fish species richness (no. of species 125 m^{-2}), B. density (no. of individuals ha^{-1} x 1000), C. biomass (mt ha^{-1}), and D. diversity (H') among sampling locations at PUHE.

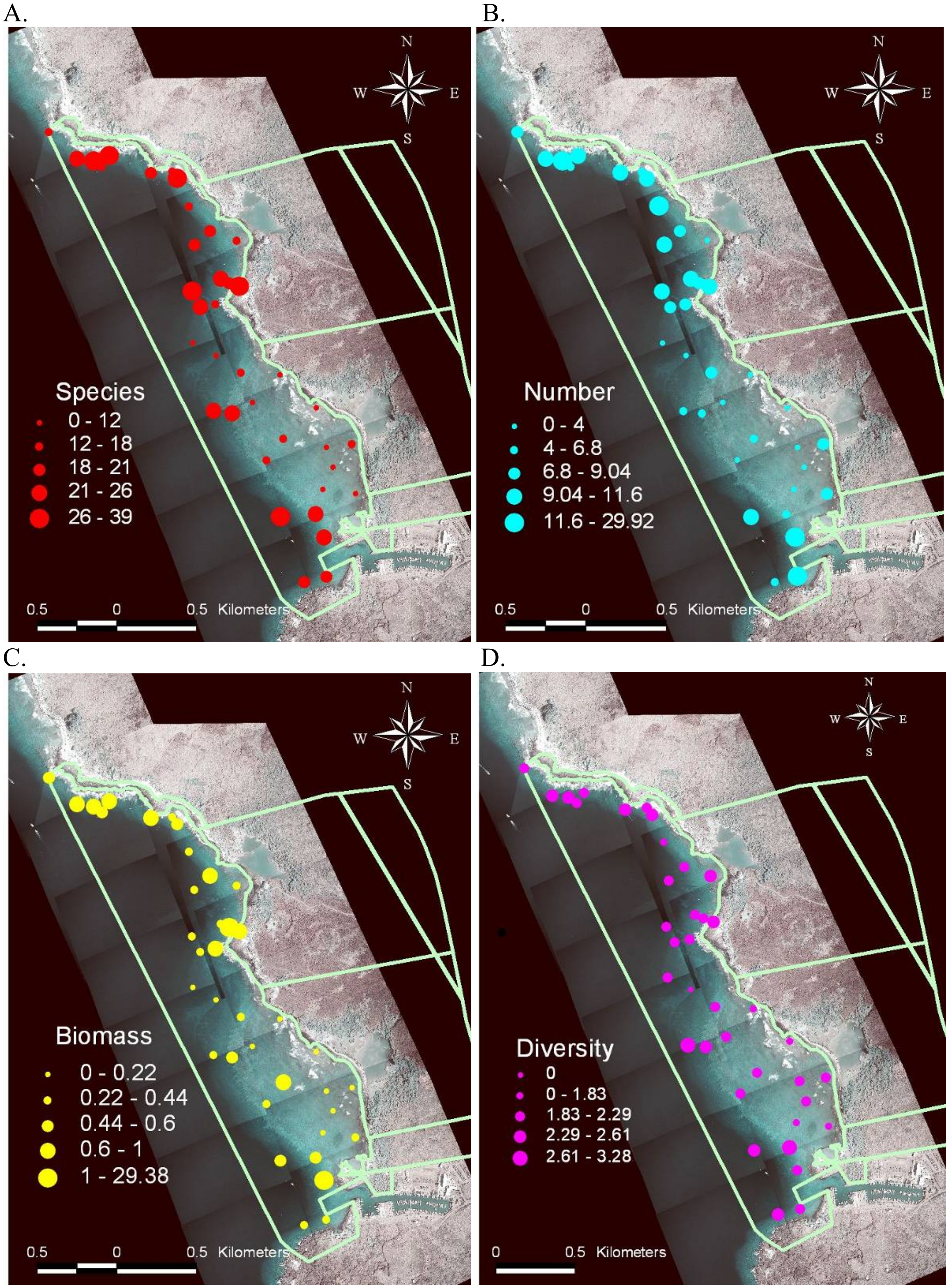


Figure 14. Spatial distribution of A. fish species richness (no. of species 125 m^{-2}), B. density (no. of individuals ha^{-1} x 1000), C. biomass (mt ha^{-1}), and D. diversity (H') among sampling locations at KAHO.

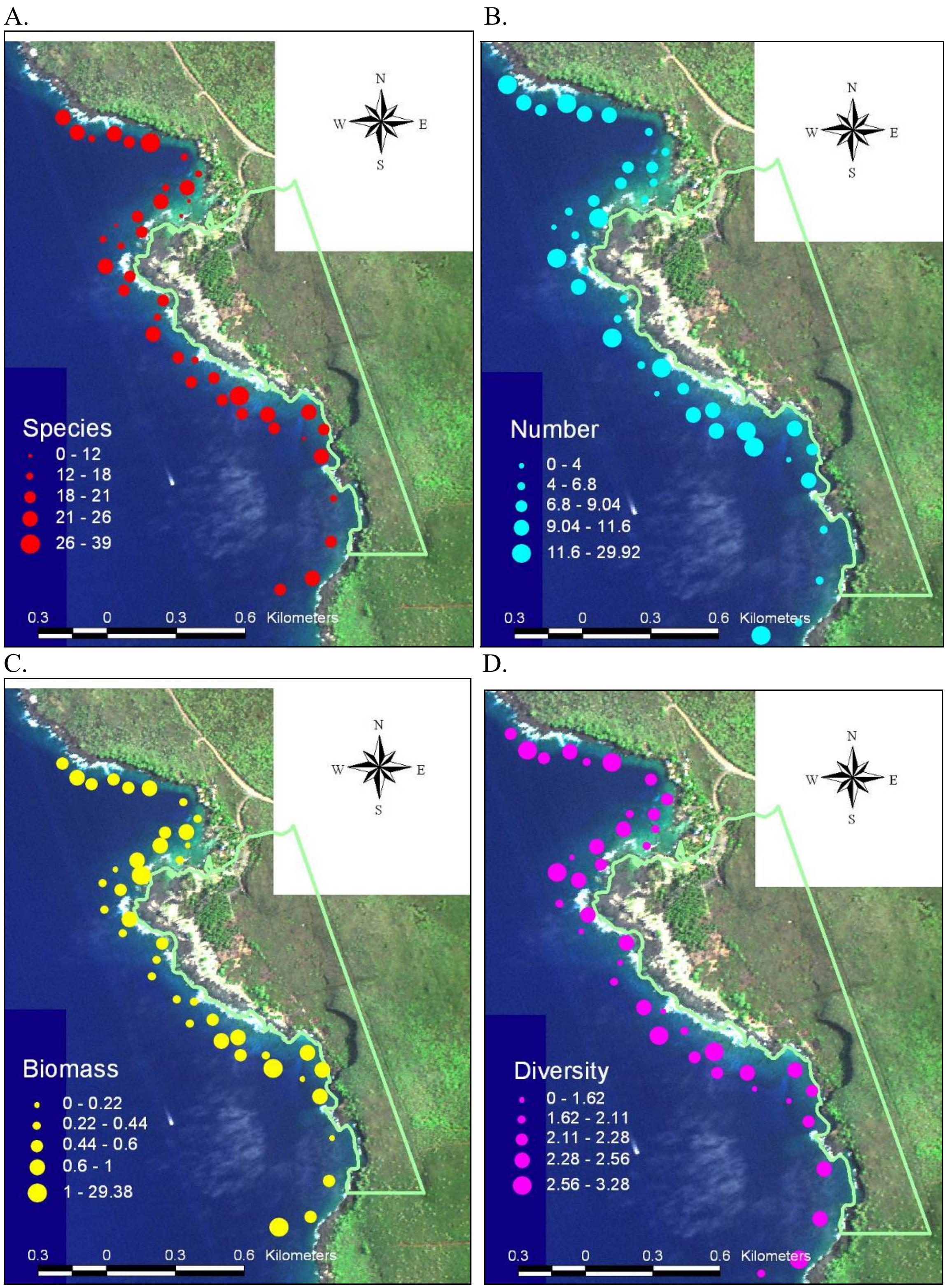


Figure 15. Spatial distribution of A. fish species richness (no. of species 125 m^{-2}), B. density (no. of individuals ha^{-1} x 1000), C. biomass (mt ha^{-1}), and D. diversity (H') among sampling locations at PUHO.

Habitat comparisons among parks

A total of 141 transects were used to characterize the benthic assemblages across all of the parks. The most abundant substrate type among the four parks was turf algae, which averaged 56% cover. Percent turf algae cover ranged from 28% (± 9% SE) at PUHE on Hawai‘i to 67% (± 4% SE) at KALA on the island of Moloka‘i (Table 6, Figure 16). Total coral cover averaged 19% for all parks and ranged from 8% (± 1% SE) at KALA to 34% (± 3% SE) at PUHO. In general, average coral cover was higher on the Hawai‘i Island parks compared to KALA on the island of Moloka‘i. Sand averaged 10% cover overall and was most prevalent at PUHE (27% ± 12%SE) and least abundant at KAHO (7% ± 3%SE). Coralline algae averaged 8% cover among all of the parks with higher average coverage at PUHE (17% ± 8%SE) compared to KALA with only 6% ± 1%SE average cover. Macroinvertebrate cover averaged 4% with the highest abundance found at KAHO (13% ± 3%SE) and the lowest abundance at PUHE (<1%). It should be noted, however, that the sampling design (e.g. diurnal) did not target macroinvertebrates. Macroalgae averaged 3% overall, and was most abundant at KALA (4% ± 1%SE) compared to PUHE (1% ± 1%SE). Seagrasses were not abundant, but were documented in the nearshore areas of PUHE (3%).

For the focal benthic taxa, coral cover was significantly higher than macroalgae cover within each park (Figure 17). PUHO had the largest difference between taxonomic groups (16-fold) compared to KALA which had roughly twice as much coral coverage as macroalgae cover.

Multivariate analysis revealed that two benthic assemblages clustered by island (Figure 18). KALA on the island of Moloka‘i, generally had lower percent cover of *Porites lobata* and *P. compressa* than the Hawai‘i Island parks (Table 6). In contrast, percent cover of turf algae, macroalgae, and *Pocillopora meandrina* were higher at KALA than at the other three parks. Specific taxonomic differences among parks included higher levels of *Anthelia edmondsonii* at KAHO compared to other parks, high densities of coralline algae and significant coverage of *Halophila* sp. in sand substrate at PUHE, and high coverage of *Porites lobata* at PUHO. *Montipora* spp. were generally not prevalent at the parks with the exception of PUHE (Table 6).

Rugosity values varied by habitat type and to a lesser degree by park (Table 7). Hard bottom habitats displayed higher rugosity than sand habitats by a factor of 1.4 to 1.7. PUHE had the highest mean rugosity values (42.7 ± 8.3) on coral reef hardbottom substrates followed by PUHO (38.4 ± 6.4), KALA (37.8 ± 7.1), and KAHO (34.0 ± 4.0). KALA had the highest maximum value of 60.0 and 4 of the top 5 rugosity values were measured in this park.

Table 6. *The 10 dominant benthic taxa/substrate types by percent cover among the four national parks surveyed in this study. Values are averaged across all transects and habitat types within a park.*

Substrate Type	Taxon	%	Substrate Type	Taxon	%
KALA			**KAHO**		
Turf algae		66.8	Turf algae		52.5
Sand		13.9	Coral	*Porites lobata*	13.0
Coralline algae		6.3	Macroinvertebrate	*Anthelia edmondsonii*	10.1
Coral	*Pocillopora meandrina*	4.3	Coralline algae		8.1
Coral	*Porites lobata*	1.7	Sand		6.7
Macroalgae	*Padina* sp.	0.8	Coral	*Pocillopora meandrina*	2.7
Macroalgae	Cyanobacteria	0.7	Coral	*Porites compressa*	1.7
Macroinvertebrate	*Palythoa caesia*	0.6	Macroinvertebrate	*Echinometra mathaei*	1.0
Macroalgae	*Lobophora* sp.	0.5	Macroinvertebrate	*Hipponix imbricatus*	1.0
Macroalgae	*Dictyota* sp.	0.4	Macroalgae	Cyanobacteria	0.5
PUHE			**PUHO**		
Turf algae		27.5	Turf algae		50.0
Sand		26.8	Coral	*Porites lobata*	15.4
Coralline algae		17.0	Coral	*Porites compressa*	10.0
Silt		11.4	Coralline algae		7.7
Coral	*Porites lobata*	6.4	Sand		3.2
Plant	*Halophila* sp.	3.0	Coral	*Pocillopora meandrina*	2.7
Coral	*Montipora capitata*	2.8	Coral	*Montipora capitata*	0.8
Coral	*Porites compressa*	2.2	Coral	*Porites evermanni*	0.6
Macroalgae		1.1	Macroalgae	*Tolypiocladia* sp.	0.6
Coral	*Montipora patula*	0.6	Macroalgae	*Lobophora* sp.	0.3

Table 7. *Mean rugosity among subtidal habitat types for each park. Standard deviations are presented in parentheses; sample sizes are presented under N. * = Habitat not present in park. Note that rugosity was not measured on every transect, in comparison to Table 3.*

	KALA		N	PUHE		N	KAHO		N	PUHO		N
Coral reef Hardbottom	39.4	(9.24)	31	42.7	(8.80)	6	33.4	(3.66)	30	40.0	(5.90)	40
Aggregated reef				48.0		1	36.3	(4.72)	4	43.6	(6.17)	12
Scattered coral				43.5	(9.68)	4						
Pavement	31.0	(2.16)	4	34.0		1	30.6	(1.81)	10	36.2	(5.12)	6
Volcanic rock	40.7	(9.24)	27						16	35.8	(3.84)	22
Uncolonized reef Hardbottom	35.2	(4.44)	15			*	34.6	(6.94)	6			*
Pavement	31.3	(2.89)	3				31.0	(6.24)	4			
Volcanic rock	36.2	(4.30)	12				40.0	(4.24)	2			
Unconsolidated	25.9	(0.69)	7	25.3	(0.58)	3	25.0	(0)	2	26.0		1
Mud			*	25.5	(0.71)	2			*			*
Sand	25.9	(0.69)	7	25.0		1	25.0	(0)	2	26.0		1
Overall	36.4	(8.67)	53	36.9	(11.12)	9	33.1	(4.59)	38	37.9	(6.13)	41

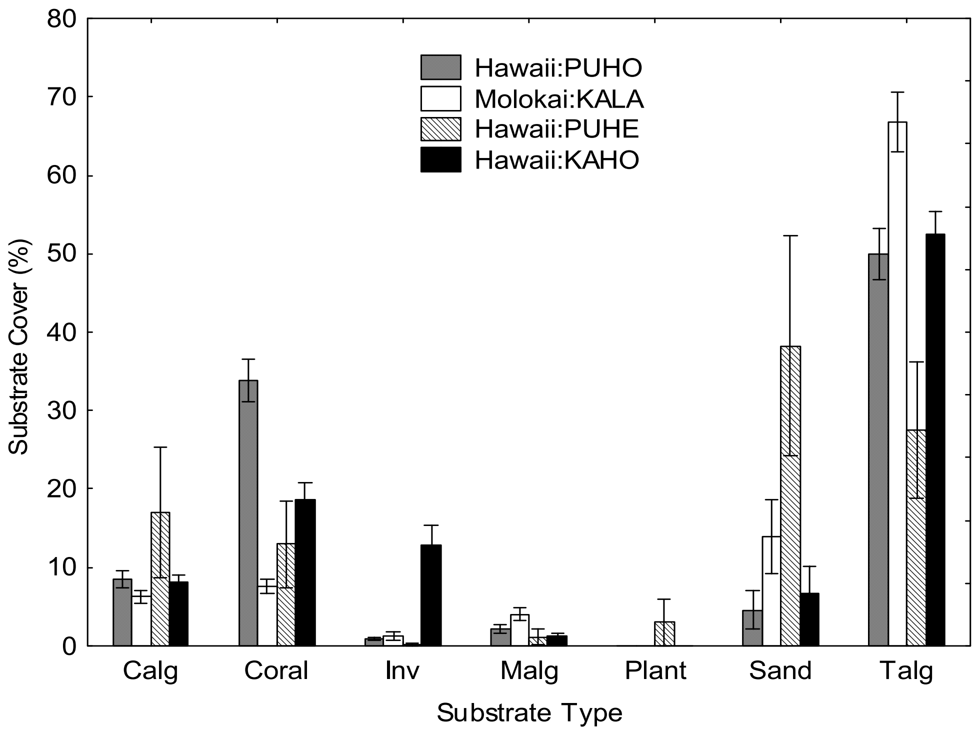


Figure 16. Percent cover (mean ± SE) of substrate types among the four national parks. Calg = Coralline algae, Coral = Living coral, Inv = Macroinvertebrates, Malg = Macroalgae, Sand = Sand, Talg = Turf algae.

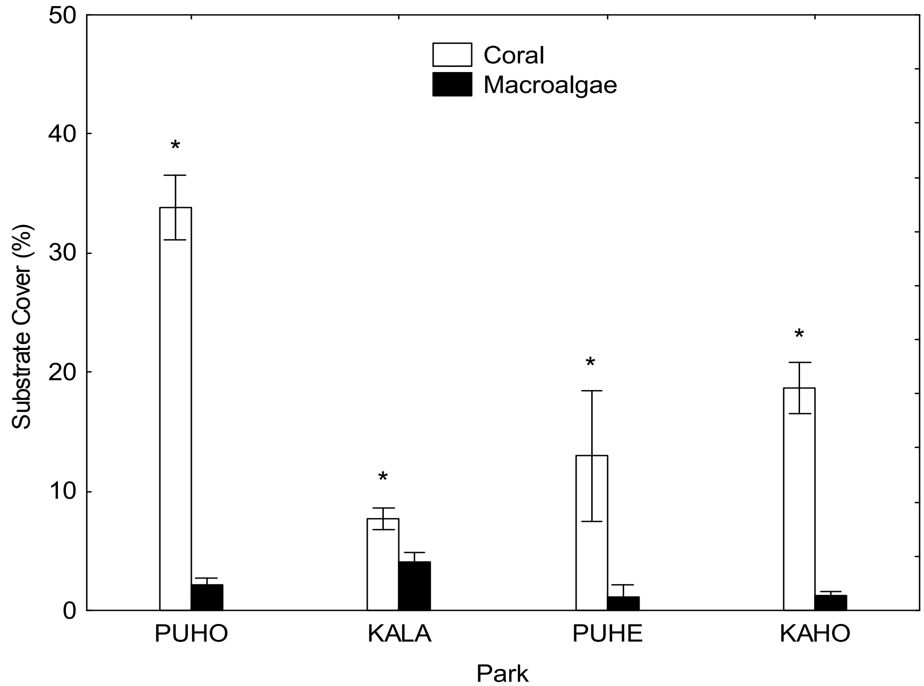


Figure 17. Percent cover (mean ± SE) of the focal benthic taxa (coral and macroalgae) among the four national parks. Significant differences between focal benthic taxa at $p<0.05$ within each park are indicated with an *.

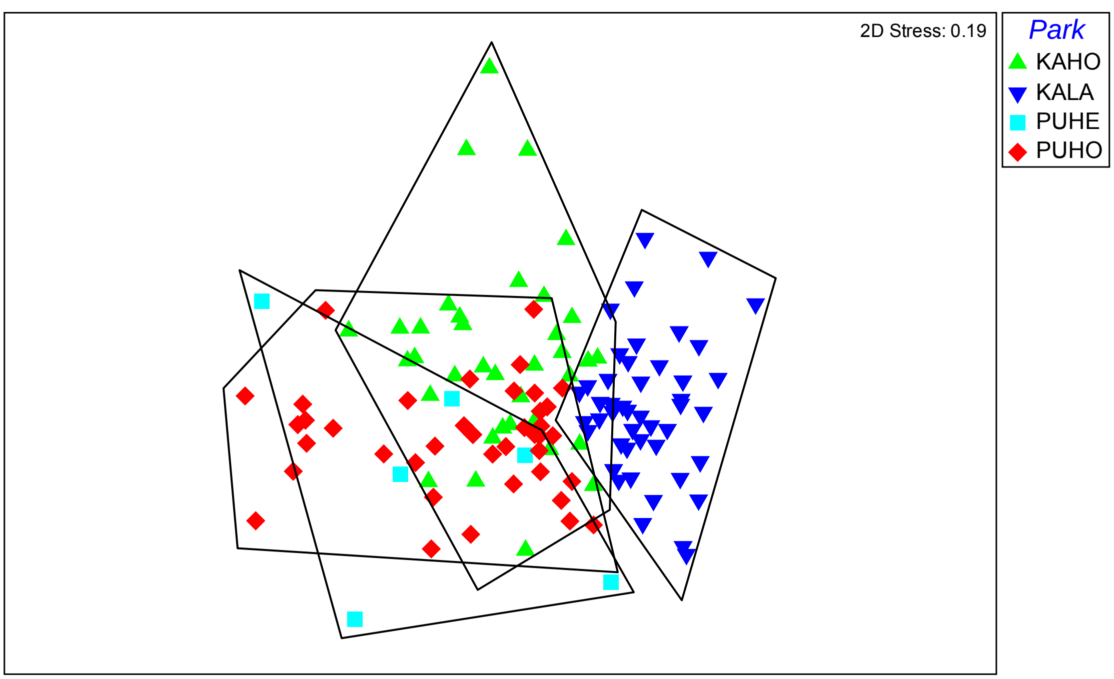


Figure 18. Multidimensional scaling (MDS) plot of average percent benthic cover on hard bottom substrates among the four national parks. The parks on Hawai‘i Island had a higher concordance in the benthic assemblages than KALA on the island of Moloka‘i.

Shoreline Sampling

Shoreline sampling was conducted adjacent to the benches, pavements, and beaches in KAHO and PUHO. The shoreline environments between these two parks on the Kona coast of the big island of Hawai‘i are very similar. Most of the coast is lava bench, with a break that drops 2-5 m in depth to rubble/boulder habitat with very low coral cover, (<5%). KAHO has extensive sand beaches that gently slope to deeper offshore zones; however, the fish assemblages in these sections were similar to other shoreline sections but with smaller individuals of representative species. Only a few marine fishes were observed in one of the two park units (Appendix A). The greatest species richness values were observed in areas with less wave exposure. No other significant differences were observed among the shoreline sections of these two parks.

Tidal Pool Sampling

Tide pools at KALA, KAHO, and PUHO were qualitatively sampled to provide species lists of fishes for this habitat. Tidal pools are not present along the small section of shoreline in PUHE.

Most fish species observed in tidal pools were juveniles of nearshore marine species (Appendix A). Only two species were observed exclusively in tide pools, *Istiblennius zebra* (zebra rockskipper) and *Bathygobius cocosensis* (Cocos frill goby). These species were very abundant in smaller tidal pools with limited access to the coastal environment in KALA, KAHO, and PUHO.

Marine mammals and turtles

The threatened green sea turtle (*Chelonia mydas*) is commonly observed on the beaches in KAHO and PUHO, as well as in the nearshore waters of KALA (Appendix A). This species has been studied intensively at KAHO. The endangered hawksbill turtle (*Eretmochelys imbricata*) has been observed in KAHO and is an expected transient in all Hawaiian parks (S. Beavers, M. Laber, NPS, personal observations).

The most common marine mammals observed in national parks in Hawai‘i are dolphins, primarily the spinner dolphin (*Stenella longirostris*) and the common bottlenose dolphin (*Tursiops truncates*) in the family Delphinidae (Appendix A). Whales (humpback whale, *Megaptera novaeangliae*, and Cuvier’s beaked whale, *Ziphius cavirostris*) are commonly observed offshore (and occasionally within park waters). The other common marine mammalian visitor is the Hawaiian monk seal (*Monachus schauinslandi*), which was observed during this investigation at KALA and KAHO and has been observed at PUHO (S. Beavers, E. Brown, M. Laber, NPS, personal observations).

DISCUSSION

Results from the present investigation

The four national parks included in this investigation had an impressive species richness of marine fishes, with a large percentage (27%) of endemic species. Results of analyses showed that the marine fish assemblages among these parks were quite varied. Habitat differences and fishing pressure were probably the greatest contributing factors for the observed differences in assemblage structure. Fishes at KALA were generally larger and more speciose, probably due the high habitat complexity at selected sites and less fishing pressure overall than at the other parks. KAHO and PUHO were quite similar in fish assemblage structure, due to similarities in habitat characteristics and fishing pressure. PUHE had the most depressed fauna, due to multiple anthropogenic impacts such as harbor construction and upland erosion (Cheney et al. 1977).

During the inventory of marine fishes in the four national parks, we observed 178 species, 52.4% of the known reef and shore fishes, using non-destructive methods (visual surveys, nets). A goal of NPS inventory projects is to survey of 90% of species found within the park boundaries. The only effective way to approach sampling 90% of the marine fishes in these environments would require the use of ichthyocides, which were not permitted during this investigation. Investigations using ichthyocides in Hawai‘i have collected numerous cryptic and nocturnal species (Greenfield 2003). During a recent investigation in Buck Island Reef National Monument in the US Virgin Islands (Caribbean Sea), only 38% of the 228 species collected with ichthyocides were observed in visual samples. However, visual sampling accounted for 34 species that were not captured using ichthyocides (Smith-Vaniz et al. 2006). Consequently, a comprehensive species list for parks with marine environments would require the use of several methods, not all of which are available.

The subtidal environments varied considerably among parks. KALA had the most unique coastal environments among the four parks, with deeper water environments dominated by large boulders from inshore benches and pavement into offshore slopes. This boulder environment had high spatial complexity, with the largest rugosity measurement recorded, providing shelter for numerous inshore fishes. The boulder environment yielded species richness values nearly as great as the coral-dominated zones in KAHO and offshore of PUHO.

The coastal environments in KAHO and offshore of PUHO had impressive coral communities interspersed among hardbottom habitats with very low coral cover and low spatial complexity. Large species richness values were associated with the high density coral communities. These coral communities were located in less wave-exposed environments than the boulder habitats at KALA.

The coastal environments offshore of PUHE are highly degraded from the combination of terrestrial run-off and harbor development (Cheney et al. 1977). Inshore waters are very turbid with most of the rocks and dead coral colonies covered with silt and algae. The lowest species richness values were obtained in the environments off PUHE. Farther offshore (>500 m) water quality improved as did the benthic habitat quality.

Marine turtles and marine mammals occupy the waters adjacent to these parks. Few marine turtles were observed in KALA and PUHE, but they commonly basked on the beaches of KAHO and PUHO and fed on algae along the shoreline.

Whales and dolphins are frequently observed at KAHO and PUHO, and to a lesser degree at KALA. The Hawaiian monk seal are also observed at these parks with KALA being the premier pupping area in the main Hawaiian Islands. Fewer sightings have been recorded at PUHE, which has a much smaller shoreline.

General information related to Hawaiian parks

The Hawaiian archipelago has a unique biota due to its isolation. This is particularly true for the marine fauna with extremely high rates of endemism (18-25%) for various taxonomic groups (Kay 1987). Most marine species have planktonic larvae stages allowing for long distance dispersal and subsequent adaptive radiation within isolated island groups.

The Indo-Pacific biogeographic region has the greatest marine fish diversity in the world oceans (Myers 1999). The Philippine Islands are the center of diversity in the region with a decreasing trend in diversity away from this center. Although many isolated island groups have high levels of endemism, the Hawaiian Islands have the greatest degree of marine endemism (24.3%) among the 340 species of reef and shore fishes in 99 families (Randall 1996). Over half of the species observed in coastal waters in Hawaiʻi were recorded in the national parks during this investigation, with a large proportion of endemic species. We expect that numerous cryptic species resided in the areas sampled, but were not observed.

The large historical changes in fish assemblages throughout Hawaiʻi have been presented in several publications (reviewed in Friedlander et al. 2005). Numerous factors have contributed to these changes, including sedimentation from coastal and upland development, pollution from surface waters and groundwater, species introductions, and resource exploitation, including numerous fish species.

Fishing has had apparent effects in KAHO and PUHO, based on several lines of evidence. First, measures of fish abundance, biomass, and diversity were lower at these parks in comparison to KALA, which has much lower visitor use (NPS Stats, http://www.nature.nps.gov/stats/). For example in 2008, KALA documented 60,934 visitors compared to 104,835 for KAHO and 414,667 for PUHO. Greater numbers of fishers are observed at KAHO and PUHO than at KALA, due to ease of accessibility at KAHO and PUHO; however, resource harvest surveys have not been conducted for these parks to date. Second, other studies around the archipelago (e.g., Friedlander et al. 2002, Friedlander et al. 2003, Friedlander et al. 2007) have documented higher fish assemblage characteristics in marine protected areas with similar habitats to KAHO and PUHO. Third, KAHO and PUHO are both adjacent to harbors and provide shoreline access for fishing which is otherwise limited along the West Hawaiʻi coastline. The nearest public boat launching facility to KALA is 48 km away and requires transit along a wave-exposed coastline that is seasonally inaccessible. The remoteness of this park has contributed to the higher fish assemblage characteristics. Finally, fishing gear types are restricted at KALA where visitors are only allowed to use pole and line from shore.

Previous work conducted in the marine environments adjacent to the four national parks has documented changes in marine resources. Tissot (1998) documented declines in marine resources adjacent to PUHE in 1996 with data collected in previous studies (Ball 1977, Cheney et al. 1977). In addition to changes in algal and invertebrate assemblages, he documented a 68% decline in fish abundance and large changes in fish species composition (<20 % similarity in samples, 1976 and 1996). For example, he did not record 14 of the 35 species recorded in 1976, although he observed several additional species, including the introduced to'au (blacktail snapper, *L. fulvus*). Tissot attributed these changes to sedimentation resulting from changes in upland land use and reduced circulation due to Kawaihae Harbor development.

Parrish et al. (1990) investigated relative abundance data of marine fishes at KAHO, with no additional species observed and no large differences in species abundance compared to present study results. Brasher (1996, 1999) provided species lists of fishes in ponds and brackish waters in KAHO. Two investigations provided data on marine fish abundances in Hōnaunau Bay, adjacent to PUHO (Doty 1969; Ludwig et al. 1980). Large differences in species abundances between those investigations and the present investigation were not apparent.

Summary

The inventory of marine vertebrate species in coastal waters off national parks in Hawai‘i has provided a comprehensive list of all marine vertebrates sampled/observed during the project along with a listing of all marine vertebrate species that have been observed within and/or adjacent to the designated NPS units. Information on fish species presence, species composition, relative abundance, biomass levels, spatial distribution of fish and their habitat affinities in each of the four NPS units has been provided. Additional information from existing publications, reports, and available materials has been included in the report.

The list of marine vertebrates found in KALA, KAHO, PUHO, and PUHE were dominated by nearshore marine reef fishes, and included intertidal (tide pool) fishes, diadromous fishes within stream mouths, marine reptiles (sea turtles) and marine mammals. Among all four parks, the colonized hardbottom habitat held the greatest number of species and had the highest biomass values. At KALA, the high substrate complexity due to large boulders contributed to the large species richness and biomass values.

Recommendations are that marine vertebrate inventories should be conducted in all NPS units in Hawai‘i and the Pacific, with a schedule of subsequent inventories established. If NPS desires to have a more comprehensive marine vertebrate species inventory, collaborations between NPS and local government agencies should be established to conduct sampling using ichthyocides and other gear under special permit.

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APPENDIX A. MARINE VERTEBRATE SPECIES OBSERVED AND RECORDED IN EACH NPS UNIT BY ZONE

* denotes endemic species; [a] denotes alien species; P – denotes observations made during the present investigation; R – denotes records from previous investigations and not observed during present investigation (Doty 1969, Cheney et al. 1977, Ludwig et al. 1980, and Tissot 1998).
KALA – Kalaupapa National Historical Park; PUHE – Puʻukoholā Heiau National Historic Site; KAHO – Kaloko-Honokōhau National Historical Park; PUHO – Puʻuhonua o Hōnaunau National Historical Park

Family/Species	**KALA**		**PUHE**		**KAHO**			**PUHO**	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
Marine Fishes									
Family Carcharhinidae									
Carcharhinus melanopterus			P						
blacktip reef shark									
Galeocerdo cuvier					R				
tiger shark									
Triaenodon obesus					R				
whitetip reef shark									
Family Sphyrnidae									
Sphyrna lewini	R								
scalloped hammerhead									
Family Myliobatidae									
Aetobatus narinari	R				P		P	P	
spotted eagle ray									
Family Mobulidae									
Manta birostris					P				
manta									
Family Elopidae									
Elops hawaiensis	P								
Hawaiian tenpounder									
Family Muraenidae									
Echidna nebulosa			P	P	P				
snowflake moray									
Gymnomuraena zebra					R				
zebra moray									
Gymnothorax flavimarginatus	P		P	P	P	P	P	P	
yellowmargin moray									
G. meleagris	P				P		P	P	P
whitemouth moray									
G. eurostus								P	
stout moray									
G. javanicus					R				
giant moray									
G. undulatus					R			P	
undulated moray									
*G. sp.***		P		P		P	P		
Scuticaria tigrina					P				
tiger moray									
Family Ophichthidae									
Brachysomophis crocodilinus					P				
crocodile snake eel									
*Myrichthys magnificus**								P	
magnificent snake eel									
Family Congridae									

Family/Species	**KALA**		**PUHE**		**KAHO**			**PUHO**	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
*Ariosoma marginatum**	P								
large-eye conger									
Conger cinereus			P		R				
mustache conger									
Gorgasia hawaiiensis					P			P	
Hawaiian garden eel									
Family Engraulidae									
Encrasicholina purpurea					R				P
Hawaiian anchovy									
Family Chanidae									
Chanos chanos				P	P			R	
milkfish									
Family Synodontidae									
Saurida spp.					R				
Synodus ulae	P				P			P	
ulae									
S. binotatus					P			P	
twospot lizardfish									
*S. sp.***				P			P		
Trachinocephalus myops	P								
snakefish									
Family Belonidae									
Tylosurus crocodilus							P		P
houndfish									
Platybelone argalus								P	
keeltail needlefish									
Family Hemiramphidae									
Hemiramphus depauperatus					R				
Polynesian halfbeak									
Hyporhamphus acutus	R								
acute halfbeak									
Family Holocentridae									
Myripristis amaena					P				
brick soldierfish									
Myripristis berndti	P				P			P	
bigscale soldierfish									
M. kuntee	P				P			P	
epaulette soldierfish									
*M. sp.***				P			P		
Neoniphon sammara	P			P	P			P	
spotfin squirrelfish									
Sargocentron diadema	P							R	
crown squirrelfish									
S. tiere								P	
Tahitian squirrelfish									
S. spiniferum								P	
saber squirrelfish									
*S. xantherythrum**					P			P	
Hawaiian squirrelfish									
*S. sp.***				P					
Family Aulostomidae									
Aulostomus chinensis	P			P	P		P	P	
trumpetfish									
Family Fistulariidae									

Family/Species	KALA		PUHE		KAHO			PUHO	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
Fistularia commersonii					P		P	P	P
cornetfish									
Family Scorpaenidae									
_Dendrochirus barberi_*					P				
Hawaiian lionfish									
Scorpaenodes littoralis					P				
cheekspot scorpionfish									
_Scorpaenopsis cacopsis_*	P							P	
titan scorpionfish									
S. diabolus	P								
devil scorpionfish									
_Sebastapistes ballieui_*					P			P	
spotfin scorpionfish									
S. coniorta	P		P		P			P	
speckled scorpionfish									
Taenianotus triacanthus					R				
leaf scorpionfish									
Family Caracanthidae									
_Caracanthus typicus_*	P		P		P			P	
Hawaiian orbicular velvetfish									
Family Serranidae									
Cephalopholis argus [a]	P		P	P	P		P	P	P
peacock grouper									
_Pseudoanthias bicolor_*					P				
bicolor anthias									
_P. thompsoni_*					R				
Thompson's anthias									
Family Kuhliidae									
_Kuhlia sandvicensis_*	R	P	R		R	P			P
Hawaiian flagtail									
K. xenura					P				
Family Priacanthidae									
Heteropricanthus cruentatus					R				
glasseye									
_Priacanthus meeki_*	P			P					
Hawaiian bigeye									
Family Cirrhitidae									
Amblycirrhitus bimacula					P				
twospot hawkfish									
Cirrhitops fasciatus	P				P		P	P	
redbarred hawkfish									
Cirrhitus pinnulatus	P			P	P		P	P	P
stocky hawkfish									
Paracirrhites arcatus	P		R	P	P		P	P	
arc-eye hawkfish									
P. forsteri	P			P	P		P	P	
blackside hawkfish									
Family Cheilodactylidae									
Cheilodactylus vittatus	P								
Hawaiian morwong									
Family Apogonidae									
Apogon kallopterus	P				P				
iridescent cardinalfish									

Appendix A continued

Family/Species	KALA		PUHE		KAHO			PUHO	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
A. taeniophorus					R				
reef-flat cardinalfish									
*Apogon sp.***									
Family Malacanthidae									
Malacanthus brevirostris					P				
flagtail tilefish									
Family Carangidae									
Caranx melampygus	P			P	P		P	P	P
bluefin trevally									
C. sexfasciatus				P					
bigeye travally									
Decapterus macarellus	R				R		P		
mackerel scad									
*D. sp.***	P				P				
Gnathanodon speciosus					R				
golden trevally									
Scomberoides lysan	P			P	R		P		
leatherback									
Selar crumenophthalmus					R				
bigeye scad									
Seriola dumerili	P				R			R	
greater amberjack									
Family Lutjanidae									
Aphareus furca	P			P	P		P	P	
smalltooth jobfish									
Aprion virescens	P							P	
green jobfish									
Lutjanus fulvus [a]	P		P	P	P		P		
blacktail snapper									
L. kasmira [a]	P			P	P		P	P	
bluestripe snapper									
Family Lethrinidae									
Monotaxis grandoculis	P			P	P		P	P	
bigeye emperor									
Family Polynemidae									
Polydactylus sexfilis					R			R	
six-fingered threadfin									
Family Mugilidae									
Mugil cephalus			P						
striped mullet									
Neomyxus leuciscus						P			P
sharpnose mullet									
Family Mullidae									
Mulloidichthys flavolineatus	P		P	P	P	P	P	P	P
yellowstripe goatfish									
M. pflugeri					P				
Pfluger's goatfish									
M. vanicolensis	P			P	P		P	P	
yellowfin goatfish									
Parupeneus insularis	P		P	P	P		P	P	
doublebar goatfish									
P. cyclostomus	P		R	P	P		P	P	
blue goatfish									
P. multifasciatus	P		P	P	P		P	P	
manybar goatfish									

Family/Species	**KALA**		**PUHE**		**KAHO**			**PUHO**	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
P. pleurostigma	P				P			R	
sidespot goatfish									
*P. porphyreus**	P			P	P		P	R	
whitesaddle goatfish									
Family Kyphosidae									
Kyphosus bigibbus	P				P				
gray chub									
K. cinerascens					P				
Highfin chub									
*K. hawaiiensis**	P								
K. sandvicensis					P				
K. vaigiensis	P				P			P	
lowfin chub									
*K. spp.***	P			P	P		P		P
Family Chaetodontidae									
Chaetodon auriga	P		P	P	P		P	P	P
threadfin butterflyfish									
C. citrinellus									P
Speckled butterflyfish									
C. ephippium	R			P	P		P		
saddleback butterflyfish									
*C. fremblii**	P							R	
bluestripe butterflyfish									
C. kleinii					P				
blacklip butterflyfish									
C. lineolatus				P	P		P	P	
lined butterflyfish									
C. lunula	P	P	P	P	P	P	P	P	P
raccoon butterflyfish									
C. lunulatus	R		P	P	P		P	P	
oval butterflyfish									
*C. miliaris**	P		R	P	P		P	R	
milletseed butterflyfish									
*C. multicinctus**	P		R	P	P		P	P	
multiband butterflyfish									
C. ornatissimus	P		P	P	P		P	P	
ornate butterflyfish									
C. quadrimaculatus	P		P	P	P		P	P	P
fourspot butterflyfish									
C. reticulatus							P	P	
reticulated butterflyfish									
C. unimaculatus	P		P	P				P	
teardrop butterflyfish									
Forcipiger flavissimus	P			P	P		P	P	
forcepsfish									
F. longirostris	P			P	P		P	P	
longnose butterflyfish									
Hemitaurichthys polylepis				P	P			P	
pyramid butterflyfish									
H. thompsoni					P		P		
Thompson's butterflyfish									
Heniochus diphreutes				P	P				
pennantfish									
Family Pomacanthidae									

Family/Species	KALA		PUHE		KAHO			PUHO	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
Centropyge fisheri*					P			P	
fisher's angelfish									
C. potteri*	P				P			P	
Potter's angelfish									
C. loricula								P	
flame angelfish									
Desmoholacanthus arcuatus*	P				R			R	
bandit angelfish									
Family Oplegnathidae									
Oplegnathus punctatus	P								
spotted knifejaw									
Family Pomacentridae									
Abudefduf abdominalis*	P	P	P	P	P	P	P	P	P
Hawaiian sergeant									
A. sordidus	P	P	P	P	P	P	P	P	P
blackspot sergeant									
A. vaigiensis	P	P	P	P	P	P	P	P	P
Indo-Pacific sergeant									
Chromis agilis	P			P	P		P	P	
agile chromis									
C. hanui*	P		R		P		P	P	
chocolate-dip chromis									
C. ovalis*	P		P		P		P	P	
oval chromis									
C. vanderbilti	P		P	P	P		P	P	
blackfin chromis									
C. verater*	P				P			P	
threespot chromis									
Dascyllus albisella*	P		P	P	P		P	P	
Hawaiian dascyllus									
Plectroglyphidodon imparipennis	P	P	P	P	P	P	P	P	P
brighteye damselfish									
P. johnstonianus	P			P	P		P	P	
blue-eye damselfish									
P. sindonis*	P				P				
rock damselfish									
Stegastes fasciolatus	P	P	P	P	P		P	P	
Pacific gregory									
Family Labridae									
Anampses chrysocephalus*	P				P				
psychedelic wrasse									
A. cuvier*	P			P	P				
pearl wrasse									
Bodianus bilunulatus*	P				P			P	
Hawaiian hogfish									
Cheilio inermis				P	R				
cigar wrasse									
Coris flavovittata*	P		R		R			R	
yellowstriped coris									
C. gaimard	P		R	P	P		P	P	P
yellowtail coris									
C. venusta*	P		P	P	P		P	P	

Family/Species	**KALA** Subtidal	**KALA** Tidepool	**PUHE** Subtidal	**PUHE** Shoreline	**KAHO** Subtidal	**KAHO** Tidepool	**KAHO** Shoreline	**PUHO** Subtidal	**PUHO** Tidepool
elegant coris									
*Cymolutes lecluse**					R			P	
Hawaiian knifefish									
Gomphosus varius	P		P	P	P		P	P	
bird wrasse									
Halichoeres ornatissimus	P		R	P	P		P	P	
ornate wrasse									
*Labroides phthirophagus**	P		P	P	P		P	P	
Hawaiian cleaner wrasse									
*Macropharyngodon geoffroy**	P				P			P	
shortnose wrasse									
Novaculichthys taeniourus				P	P		P	P	P
rockmover wrasse									
Oxycheilinus bimaculatus	P				P			P	
twospot wrasse									
O. unifasciatus			P	P	P		P	P	
ringtail wrasse									
Pseudocheilinus evanidus	P				P			P	
disappearing wrasse									
P. octotaenia	P			P	P		P	P	
eightstripe wrasse									
P. tetrataenia	P				P		P	P	
fourstripe wrasse									
Pseudojuloides cerasinus	P				P			P	
smalltail wrasse									
*Stethojulis balteata**	P	P	P	P	P	P	P	P	P
belted wrasse									
*Thalassoma ballieui**	P		P					R	
blacktail wrasse									
*T. duperrey**	P	P	P	P	P	P	P	P	P
saddle wrasse									
T. lutescens				P				R	
sunset wrasse									
T. purpureum	P			P	P	P	P	P	
surge wrasse									
T. quinquevittatum				P	P				
fivestripe wrasse									
T. trilobatum	P	P		P	P	P	P	P	P
Christmas wrasse									
Xyrichtys aneitensis					P				
whitepatch razorfish									
*X. umbrilatus**	P				P				
blackside razorfish									
Family Scaridae									
Calotomus carolinus	P			P	P		P	P	
stareye parrotfish									
*Chlorurus perspicillatus**	P		P	P	P		P	R	
spectacled parrotfish									
C. sordidus	P		P	P	P		P	P	
bullethead parrotfish									
*Scarus dubius**	P		R		P		P	P	
regal parrotfish									
S. psittacus	P		P	P	P		P	P	

Appendix A continued

Family/Species	KALA		PUHE		KAHO			PUHO	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
palenose parrotfish									
S. rubroviolaceus	P		P	P	P		P	P	
redlip parrotfish									
S. sp.**			P					P	
Family Ammodytidae									
Ammodytoides pylei	P								
Pyle's sandlance									
Family Blenniidae									
Cirripectes obscurus*							P		
gargantuan blenny									
C. vanderbilti*	P			P	P		P	P	
scarface blenny									
Exallias brevis	P			P	P		P		
shortbodied blenny									
Istiblennius zebra*		P			R	P			P
zebra rockskipper									
Plagiotremus ewaensis*	P				P		P	P	
ewa fangblenny									
P. goslinei*	P			P	P		P	P	
Gosline's fangblenny									
Family Gobiidae									
Asteropteryx semipunctatus			P						
halfspotted goby									
Bathygobius cocosensis		P				P			P
Cocos frill goby									
Coryphopterus sp.			P						
Hawaiian sand goby									
Oxyurichthys lonchotus					R				
Psilogobius mainlandi*			P						
Hawaiian shrimp goby									
Family Microdesmidae									
Gunnellichthys curiosus	P				P				
curious wormfish									
Nemateleotris magnifica								P	
fire dartfish									
Family Eleotridae									
Eleotris sandwicensis					R				
sandwich island sleeper									
Family Zanclidae									
Zanclus cornutus	P		R	P	P		P	P	
Moorish idol									
Family Acanthuridae									
Acanthurus achilles	P		P	P	P		P	P	
Achilles tang									
A. blochii	P		P	P	P		P	P	
ringtail surgeonfish									
A. dussumieri	P		P	P	P		P	P	
eyestripe surgeonfish									
A. guttatus	R			P	P		P	P	
whitespotted surgeonfish									
A. leucopareius	P		R	P	P		P	P	
whitebar surgeonfish									
A. maculiceps								P	
white-freckled surgeonfish									

Appendix A continued

Family/Species	**KALA**		**PUHE**		**KAHO**			**PUHO**	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
A. nigricans				P	P		P	P	
goldrim surgeonfish									
A. nigrofuscus	P		P	P	P		P	P	P
brown surgeonfish									
A. nigroris	P		P	P	P		P	P	
bluelined surgeonfish									
A. olivaceus	P		P	P	P		P	P	
orangeband surgeonfish									
A. thompsoni					P			P	
Thompson’s surgeonfish									
A. triostegus	P		P	P	P	P	P	P	P
convict surgeonfish									
A. xanthopterus	P		P	P				R	
yellowfin surgeonfish									
Ctenochaetus hawaiiensis	P			P	P		P	P	
black surgeonfish									
C. strigosus	P		P	P	P		P	P	
goldring surgeonfish									
Naso brevirostris	P				P		P	R	
paletail unicornfish									
N. caesius					P				
gray unicornfish									
N. hexacanthus	P				P			P	
sleek unicornfish									
N. lituratus	P		P	P	P	P	P	P	P
orangespine unicornfish									
N. unicornis	P			P	P		P	P	
bluespine unicornfish									
Zebrasoma flavescens	P			P	P		P	P	
yellow tang									
Z. veliferum	P		R	P	P		P	P	
sailfin tang									
Family Sphyraenidae									
Sphyraena barracuda	R				P				
great barracuda									
S. helleri					P				
Heller’s barracuda									
Family Bothidae									
Bothus mancus					P				
flowery flounder									
Family Balistidae									
Balistes polylepis					P			P	
finescale trigger									
Melichthys niger	P		P	P	P		P	P	
black durgon									
M. vidua	P			P	P		P	P	
pinktail durgon									
Rhinecanthus aculeatus				P	P		P	R	
lagoon triggerfish									
R. rectangulus	P		P	P	P		P	P	
reef triggerfish									
Sufflamen bursa	P			P	P		P	P	
lei triggerfish									
S. fraenatus	P				P			P	
bridled triggerfish									

Family/Species	KALA		PUHE		KAHO			PUHO	
	Subtidal	Tidepool	Subtidal	Shoreline	Subtidal	Tidepool	Shoreline	Subtidal	Tidepool
Xanthichthys auromarginatus				P	P			P	
gilded triggerfish									
Family Monacanthidae									
Aluterus scriptus				P	P			P	
scrawled filefish									
Cantherhines dumerilii	P			P	P		P	P	
barred filefish									
*C. sandwichiensis**	P			P	P		P	P	
squaretail filefish									
Pervagor aspricaudus				P	P			P	
yellowtail filefish									
*P. spilosoma**			R		R			R	
yellowtail filefish									
Family Ostraciidae									
Ostracion meleagris	P		R	P	P		P	P	P
spotted boxfish									
O. whitleyi					P				
Whitley's boxfish									
Family Tetraodontidae									
Arothron hispidus					P		P	P	P
stripebelly puffer									
A. meleagris			P	P	P		P	P	
spotted puffer									
Canthigaster amboinensis	P		P	P	P	P	P	P	P
ambon toby									
C. coronata	P				P			P	
crown toby									
*C. jactator**	P		P	P	P		P	P	P
Hawaiian whitespotted toby									
Family Diodontidae									
Diodon holocanthus			P	P	P				
spiny balloonfish									
D. hystrix				P	P		P		
porcupinefish									
Marine Turtles									
Chelonia mydas	P				P			P	
green Sea Turtle									
Eretmochelys imbricata					P				
hawksbill Sea Turtle									
Marine Mammals									
Monachus schavinslandi	P				P				
Hawaiian Monk Seal									
Stenella longirostris	P				P			P	
spinner Dolphin									
Megaptera novaeangliae	P				P				
humpback Whale									
Tursiops truncatus	P								
common Bottlenose Dolphin									
Steno bredanensis	P								
rough-toothed Dolphin									
Ziphius cavirostris					P				
Cuvier's Beaked Whale									

** Could not be identified to species

APPENDIX B. AVERAGE DENSITY AND BIOMASS OF MARINE FISH SPECIES FROM SUBTIDAL TRANSECTS SAMPLED IN THE FOUR NATIONAL PARKS

Density is given in numbers/ha, biomass is given in kg/ha. Standard deviation is presented below each value in parenthesis. KALA – Kalaupapa National Historical Park; PUHE – Puʻukoholā Heiau National Historic Site; KAHO – Kaloko-Honokōhau National Historical Park; PUHO – Puʻuhonua o Hōnaunau National Historical Park

Family/Species	**KALA**		**PUHE**		**KAHO**		**PUHO**	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Family Elopidae								
Elops hawaiensis	120.8	< 0.001						
Hawaiian tenpounder	(879.1)	(0)						
Family Muraenidae								
Echidna nebulosa					2.1	0.176		
snowflake moray					(13.0)	(1.082)		
Gymnothorax flavimarginatus					2.1	1.295		
yellowmargin moray					(13.0)	(7.982)		
G. meleagris	1.5	0.141					7.8	0.643
whitemouth moray	(11.0)	(1.025)					(24.0)	(2.155)
Family Ophichthidae								
Myrichthys magnificus							2.0	0.066
magnificent snake eel							(12.5)	(0.425)
Family Synodontidae								
Synodus ulae	1.5	0.001						
ulae	(11.0)	(0.010)						
Family Holocentridae								
Myripristis berndti	18.1	3.951			2.1	0.253		
bigscale soldierfish	(57.9)	(14.810)			(13.0)	(1.558)		
M. kuntee	1.5	0.181			6.3	0.682	134.6	12.497
epaulette soldierfish	(11.0)	(1.319)			(28.7)	(3.032)	(753.5)	(70.460)
*M. sp.**								
Neoniphon sammara	3.0	.369					2.0	0.182
spotfin squirrelfish	(15.4)	(2.000)					(12.5)	(1.168)
Sargocentron diadema	1.5	0.150						
crown squirrelfish	(11.0)	(1.089)						
S. tiere							2.0	0.736
Tahitian squirrelfish							(12.5)	(4.715)
Family Aulostomidae								
Aulostomus chinensis	3.0	0.531			4.2	0.112		
trumpetfish	(15.4)	(2.888)			(18.1)	(0.554)		
Family Fistulariidae								
Fistularia commersonii					2.1	0.167	2.0	0.045
cornetfish					(13.0)	(1.027)	(12.5)	(0.285)
Family Scorpaenidae								
Scorpaenopsis cacopsis	1.5	2.702					2.0	2.991
titan scorpionfish	(11.0)	(19.667)					(12.5)	(19.152)
S. diabolus	1.5	1.648						
devil scorpionfish	(11.0)	(11.995)						
Sebastapistes coniorta	6.0	0.023	8.9	0.050	2.1	0.012		
speckled scorpionfish	(34.5)	(0.121)	(26.7)	(0.151)	(13.0)	(0.074)		
Family Caracanthidae								
Caracanthus typicus	4.5	0.068						
Hawaiian orbicular velvetfish	(18.7)	(0.339)						
Family Serranidae								
Cephalopholis argus	32.7	20.702			61.1	15.392	29.3	9.614

Family/Species	KALA		PUHE		KAHO		PUHO	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
peacock grouper	(72.9)	(49.134)			(91.9)	(24.418)	(49.8)	(17.009)
Family Priacanthidae								
Priacanthus meeki	4.5	1.147						
Hawaiian bigeye	(18.7)	(5.231)						
Family Cirrhitidae								
Cirrhitops fasciatus	54.3	0.809					2.0	0.020
redbarred hawkfish	(96.4)	(1.527)					(12.5)	(0.125)
Cirrhitus pinnulatus	1.5	0.695						
stocky hawkfish	(11.0)	(5.059)						
Paracirrhites arcatus	359.2	7.164			275.8	4.620	335.6	5.637
arc-eye hawkfish	(394.0)	(9.508)			(319.8)	(5.889)	(333.3)	(5.844)
P. forsteri	10.6	0.850			14.7	1.046	11.7	0.849
blackside hawkfish	(31.5)	(2.826)			(36.5)	(2.720)	(33.8)	(2.540)
Family Apogonidae								
Apogon kallopterus	1.5	0.010						
iridescent cardinalfish	(11.0)	(0.076)						
Family Malacanthidae								
Malacanthus brevirostris					4.2	0.083		
flagtail tilefish					(26.0)	(0.514)		
Family Carangidae								
Caranx melampygus	37.7	25.426					2.0	2.272
bluefin trevally	(88.2)	(75.758)					(12.5)	(14.549)
Scomberoides lysan	9.1	0.878						
leatherback	(65.9)	(6.389)						
Seriola dumerili	1.5	4.523						
greater amberjack	(11.0)	(32.927)						
Family Lutjanidae								
Aphareus furca	12.1	3.376			4.2	0.597	11.7	1.871
smalltooth jobfish	(48.1)	(16.049)			(18.1)	(2.660)	(33.8)	(7.107)
Aprion virescens	3.0	4.386					2.0	0.275
green jobfish	(15.4)	(24.700)					(12.5)	(1.760)
Lutjanus fulvus	13.6	2.479	35.6	3.925				
blacktail snapper	(37.6)	(7.059)	(58.1)	(6.312)				
L. kasmira	147.9	28.171			231.6	55.491	390.2	26.641
bluestripe snapper	(415.8)	(71.637)			(1401.0)	(337.859)	(2498.8)	(170.585)
Family Lethrinidae								
Monotaxis grandoculis	18.1	17.743			14.7	11.227	11.7	9.121
bigeye emperor	(40.4)	(49.852)			(55.3)	(51.789)	(52.3)	(53.649)
Family Mullidae								
Mulloidichthys flavolineatus	10.6	2.309	8.9	1.940	2.1	0.778	3.9	0.588
yellowstripe goatfish	(47.2)	(12.000)	(26.7)	(5.819)	(13.0)	(4.796)	(25.0)	(3.768)
M. vanicolensis	37.7	18.524					78.0	14.676
yellowfin goatfish	(185.4)	(94.799)					(499.8)	(93.975)
Parupeneus insularis	28.7	6.297			18.9	4.229	23.4	5.379
doublebar goatfish	(52.3)	(12.919)			(39.2)	(10.315)	(51.4)	(12.380)
P. cyclostomus	18.1	7.586			12.6	3.503	3.9	1.127
blue goatfish	(60.0)	(28.268)			(34.9)	(10.697)	(25.0)	(7.215)
P. multifasciatus	154.0	21.039	17.8	2.531	46.3	4.798	54.6	5.278
manybar goatfish	(174.6)	(28.803)	(35.3)	(5.040)	(63.4)	(8.260)	(70.3)	(7.894)
P. pleurostigma	12.1	1.494			2.1	0.189		
sidespot goatfish	(50.6)	(5.475)			(13.0)	(1.163)		
P. porphyreus	7.5	3.547						
whitesaddle goatfish	(36.0)	(15.119)						
Family Kyphosidae								
Kyphosus bigibbus	12.1	4.345						

Appendix B continued

Family/Species	KALA		PUHE		KAHO		PUHO	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
gray chub	(57.4)	(19.138)						
K. vaigiensis	1.5	0.398					11.7	4.116
lowfin chub	(11.0)	(2.897)					(75.0)	(26.358)
*Kyphosus. sp.**	140.4	54.419						
chub species	(333.9)	(127.075)						
Family Chaetodontidae								
Chaetodon auriga	7.5	0.609	8.9	0.718	10.5	0.972	3.9	0.352
threadfin butterflyfish	(54.9)	(4.436)	(26.7)	(2.153)	(33.1)	(3.155)	(25.0)	(2.251)
C. fremblii	10.6	0.655						
bluestripe butterflyfish	(31.5)	(1.968)						
C. lineolatus					4.2	0.814		
lined butterflyfish					(26.0)	(5.019)		
C. lunula	21.1	1.154			10.5	0.636	3.9	0.216
raccoon butterflyfish	(59.0)	(3.372)			(27.4)	(1.665)	(25.0)	(1.382)
C. lunulatus							3.9	0.271
oval butterflyfish							(25.0)	(1.732)
C. miliaris	40.8	2.288			2.1	0.008		
milletseed butterflyfish	(170.9)	(9.719)			(13.0)	(0.049)		
C. multicinctus	18.1	0.809			82.1	3.575	173.7	7.135
multiband butterflyfish	(62.1)	(2.893)			(119.8)	(5.551)	(209.3)	(7.521)
C. ornatissimus	9.1	1.297	8.9	1.112	10.5	1.034	54.6	5.972
ornate butterflyfish	(40.5)	(5.950)	(26.7)	(3.336)	(33.1)	(3.957)	(93.7)	(9.370)
C. quadrimaculatus	42.3	3.661	8.9	0.866	25.3	1.849	54.6	2.916
fourspot butterflyfish	(76.2)	(6.519)	(26.7)	(2.597)	(53.0)	(3.753)	(116.5)	(6.221)
C. unimaculatus	13.6	0.834						
teardrop butterflyfish	(62.2)	(3.471)						
Forcipiger flavissimus	21.1	1.068			35.8	1.596	35.1	1.303
forcepsfish	(59.0)	(3.144)			(60.8)	(2.721)	(62.1)	(2.282)
F. longirostris	3.0	0.191			6.3	.340	11.7	0.613
longnose butterflyfish	(22.0)	(1.391)			(28.7)	(1.594)	(33.8)	(1.732)
H. thompsoni					21.1	1.728		
Thompson's butterflyfish					(129.8)	(10.655)		
Heniochus diphreutes					52.6	5.108		
pennantfish					(324.4)	(31.489)		
Family Pomacanthidae								
Centropyge fisheri					2.1	0.040	5.9	0.125
fisher's angelfish					(13.0)	(0.245)	(27.7)	(0.608)
C. potteri	6.0	0.147			21.2	0.853	27.3	0.927
Potter's angelfish	(34.5)	(0.805)			(76.0)	(3.191)	(63.5)	(2.169)
Desmoholacanthus arcuatus	18.1	3.572						
bandit angelfish	(65.9)	(12.598)						
Family Oplegnathidae								
Oplegnathus punctatus	1.5	3.485						
spotted knifejaw	(11.0)	(25.370)						
Family Pomacentridae								
Abudefduf abdominalis	93.6	6.538	8.9	0.682	136.8	8.958	3.9	0.299
Hawaiian sergeant	(236.2)	(17.359)	(26.7)	(2.046)	(477.1)	(30.640)	(25.0)	(1.917)
A. sordidus	7.5	1.050			2.1	0.253		
blackspot sergeant	(23.6)	(3.416)			(13.0)	(1.559)		
A. vaigiensis	18.1	2.845			50.5	3.671		
Indo-Pacific sergeant	(88.3)	(13.480)			(191.0)	(16.622)		
Chromis agilis	16.6	0.102			423.2	2.416	977.6	5.082
agile chromis	(70.8)	(0.472)			(1200.8)	(6.913)	(1638.3)	(9.104)
C. hanui	51.3	0.145			37.9	0.073	41.0	0.168
chocolate-dip chromis	(126.6)	(0.364)			(121.6)	(0.244)	(164.1)	(0.634)

Appendix B continued

Family/Species	KALA		PUHE		KAHO		PUHO	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
C. ovalis	224.9	9.415						
oval chromis	(605.0)	(27.285)						
C. vanderbilti	2170.6	6.346			1717.9	3.406	1512.2	3.948
blackfin chromis	(2889.6)	(8.734)			(2999.5)	(7.638)	(2626.0)	(7.018)
C. verater	259.6	18.438			2.1	0.151	3.9	0.310
threespot chromis	(754.4)	(57.861)			(13.0)	(0.931)	(17.4)	(1.392)
Dascyllus albisella	1.5	0.094			6.3	0.334		
Hawaiian dascyllus	(11.0)	(0.683)			(28.7)	(1.854)		
Plectroglyphidodon imparipennis	199.2	0.779			153.7	0.547	11.7	0.041
brighteye damselfish	(332.3)	(1.350)			(374.9)	(1.368)	(52.3)	(0.184)
P. johnstonianus	66.4	0.703			42.1	0.408	80.0	0.847
blue-eye damselfish	(138.3)	(1.818)			(73.8)	(0.779)	(1.216)	(1.216)
P. sindonis	3.0	0.046						
rock damselfish	(15.4)	(0.233)						
Stegastes fasciolatus	137.4	2.399	17.8	0.536	35.8	0.775	46.8	0.870
Pacific gregory	(189.2)	(3.450)	(35.3)	(1.064)	(90.5)	(2.866)	(77.9)	(1.507)
Family Labridae								
Anampses chrysocephalus	7.5	0.040						
psychedelic wrasse	(32.4)	(0.199)						
A. cuvier	9.1	0.749						
pearl wrasse	(37.3)	(2.824)						
Bodianus bilunulatus	104.2	54.070			6.3	1.358	3.9	0.612
Hawaiian hogfish	(107.1)	(70.109)			(28.7)	(8.365)	(17.4)	(3.905)
Coris flavovittata	3.0	1.687						
yellowstriped coris	(15.4)	(9.137)						
C. gaimard	25.7	0.272			29.5	2.322	31.2	1.538
yellowtail coris	(81.2)	(0.904)			(65.6)	(6.441)	(59.0)	(3.705)
C. venusta	24.2	0.412			2.1	0.039		
elegant coris	(72.9)	(1.372)			(13.0)	(0.243)		
Cymolutes lecluse							3.9	0.197
Hawaiian knifefish							(25.0)	(1.260)
Gomphosus varius	31.7	0.135	155.6	1.194	101.1	1.118	70.2	1.142
bird wrasse	(80.5)	(0.448)	(212.1)	(2.233)	(155.3)	(2.432)	(109.1)	(2.294)
Halichoeres ornatissimus	111.7	0.965			77.9	0.765	64.4	0.691
ornate wrasse	(153.2)	(1.293)			(92.0)	(1.124)	(86.2)	(1.013)
Labroides phthirophagus	18.1	0.035	8.9	0.035	4.2	0.009	21.5	0.042
Hawaiian cleaner wrasse	(46.1)	(0.095)	(46.1)	(0.095)	(18.1)	(0.038)	(43.9)	(0.085)
Macropharyngodon geoffroy	22.6	0.183			6.3	0.091		
shortnose wrasse	(87.9)	(0.750)			(28.7)	(0.391)		
Oxycheilinus bimaculatus	3.0	0.019					2.0	0.018
twospot wrasse	(15.4)	(0.109)					(12.5)	(0.117)
O. unifasciatus					6.3	1.705	23.4	3.977
ringtail wrasse					(28.7)	(9.476)	(60.0)	(15.775)
Pseudocheilinus evanidus	16.6	0.530			101.1	0.933	107.3	1.209
disappearing wrasse	(70.8)	(3.244)			(227.6)	(2.023)	(197.3)	(2.561)
P. octotaenia	9.1	0.152			44.2	0.659	78.0	1.042
eightstripe wrasse	(30.0)	(0.522)			(73.7)	(1.188)	(105.1)	(1.433)
P. tetrataenia	36.2	0.197			40.0	0.211	99.5	0.524
fourstripe wrasse	(94.9)	(0.498)			(63.8)	(0.329)	(141.7)	(0.809)
Pseudojuloides cerasinus	4.5	0.080			10.5	0.045	7.8	0.082
smalltail wrasse	(24.4)	(0.413)			(38.0)	(0.162)	(30.0)	(0.349)
Stethojulis balteata	129.8	1.335	115.6	1.242	136.8	1.298	17.6	0.374
belted wrasse	(238.1)	(2.495)	(230.2)	(2.913)	(236.7)	(3.129)	(42.0)	(1.078)
Thalassoma ballieui	16.6	4.137	8.9	0.703				
blacktail wrasse	(39.6)	(10.660)	(26.7)	(2.108)				

Family/Species	KALA		PUHE		KAHO		PUHO	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
T. duperrey	963.0	11.305	177.8	1.927	600.0	16.575	548.3	11.114
saddle wrasse	(925.4)	(14.800)	(285.0)	(2.855)	(516.4)	(56.436)	(455.2)	(9.247)
T. purpureum	3.0	0.228						
surge wrasse	(15.4)	(1.164)						
T. trilobatum	48.3	2.807			50.5	1.150		
Christmas wrasse	(103.3)	(5.985)			(138.5)	(3.609)		
Xyrichtys aneitensis					2.1	0.103		
whitepatch razorfish					(13.0)	(0.638)		
X. umbrilatus	12.1	0.368						
blackside razorfish	(63.5)	(1.937)						
Family Scaridae								
Calotomus carolinus	9.1	3.301			12.6	0.617	13.7	1.096
stareye parrotfish	(33.9)	(6.792)			(43.7)	(2.004)	(47.0)	(3.620)
Chlorurus perspicillatus	15.1	15.627						
spectacled parrotfish	(58.8)	(59.408)						
C. sordidus	4.5	1.736	840.0	106.456	69.5	14.029	62.4	24.316
bullethead parrotfish	(24.4)	(8.981)	(2582.1)	(148.850)	(195.2)	(27.379)	(77.0)	(30.949)
Scarus dubius	22.6	17.624					2.0	1.550
regal parrotfish	(82.1)	(66.237)					(12.5)	(9.928)
S. psittacus	111.7	32.527	977.8	68.645	193.7	26.074	27.3	8.567
palenose parrotfish	(215.9)	(70.560)	(2392.6)	(171.038)	(297.4)	(36.650)	(85.1)	(28.003)
S. rubroviolaceus	84.5	12.591	17.8	0.256	35.8	2.614	37.1	2.425
redlip parrotfish	(161.8)	(26.561)	(53.3)	(0.769)	(76.0)	(6.942)	(71.8)	(7.326)
*S. sp.**			142.2	0.030			2.0	0.001
Family Ammodytidae			(306.7)	(0.065)			(12.5)	(0.005)
Ammodytoides pylei	4.5	<0.001						
Pyle's sandlance	(33.0)	0						
Family Blenniidae								
C. vanderbilti	7.5	0.019			2.1	0.001	2.0	0.006
scarface blenny	(23.6)	(0.059)			(13.0)	(0.003)	(12.5)	(0.036)
Exallias brevis	1.5	0.041						
shortbodied blenny	(11.0)	(0.298)						
Plagiotremus ewaensis	4.5	0.006			2.1	0.003	2.0	0.003
ewa fangblenny	(24.4)	(0.034)			(13.0)	(0.018)	(12.5)	(0.017)
P. goslinei	40.8	0.057			14.7	0.020	3.9	0.002
Gosline's fangblenny	(64.0)	(0.089)			(55.3)	(0.077)	(17.4)	(0.007)
Family Gobiidae								
Asterropteryx semipunctatus			26.7	0.003				
halfspotted goby			(56.6)	(0.006)				
Coryphopterus sp.			8.9	0.001				
Hawaiian sand goby			(26.7)	(0.002)				
Psilogobius mainlandi			80.0	0.059				
Hawaiian shrimp goby			(183.3)	(0.134)				
Family Microdesmidae								
Gunnellichthys curiosus	3.0	0.002						
curious wormfish	(22.0)	(0.018)						
Family Zanclidae								
Zanclus cornutus	37.7	4.290			23.2	3.080	5.9	0.697
Moorish idol	(120.1)	(13.788)			(64.2)	(8.727)	(27.7)	(3.384)
Family Acanthuridae								
Acanthurus achilles	7.5	1.444					23.4	1.026
Achilles tang	(54.9)	(10.512)					(69.8)	(3.049)
A. blochii	27.2	8.577	62.2	2.526	2.1	0.409	5.9	0.962
ringtail surgeonfish	(87.3)	(28.410)	(111.6)	(4.347)	(13.0)	(2.519)	(27.7)	(4.992)
A. dussumieri	54.3	17.103			8.4	1.837	7.8	1.796

Appendix B continued

Family/Species	KALA		PUHE		KAHO		PUHO	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
eyestripe surgeonfish	(103.8)	(33.394)			(24.9)	(5.496)	(30.0)	(6.594)
A. leucopareius	472.5	98.189			71.6	14.991	121.0	23.634
whitebar surgeonfish	(903.6)	(186.004)			(191.3)	(40.724)	(387.9)	(75.925)
A. nigrofuscus	354.7	17.811	400.0	32.794	650.5	29.345	565.9	20.298
brown surgeonfish	(379.6)	(19.252)	(812.9)	(75.138)	(663.4)	(32.106)	(535.3)	(22.592)
A. nigroris	25.7	3.194			10.5	1.288	15.6	2.163
bluelined surgeonfish	(76.5)	(9.767)			(27.4)	(3.548)	(36.7)	(6.030)
A. olivaceus	46.8	13.196			117.9	38.264	56.6	18.714
orangeband surgeonfish	(93.4)	(26.675)			(312.2)	(109.499)	(88.1)	(34.871)
A. thompsoni					75.8	6.554	89.8	8.154
Thompson's surgeonfish					(286.3)	(25.302)	(396.1)	(38.703)
A. triostegus	227.9	21.880	115.6	11.979	48.4	2.753	19.5	1.218
convict surgeonfish	(835.7)	(84.947)	(212.1)	(22.021)	(117.0)	(8.661)	(75.4)	(4.569)
A. xanthopterus	10.6	6.322						
yellowfin surgeonfish	(76.9)	(46.025)						
Ctenochaetus hawaiiensis					6.3	1.534	46.8	10.754
black surgeonfish					(28.7)	(8.270)	(96.3)	(21.678)
C. strigosus	161.5	20.463	26.7	2.593	408.4	28.169	981.5	54.199
goldring surgeonfish	(358.6)	(51.672)	(56.6)	(5.959)	(610.6)	(44.197)	(1086.1)	(60.737)
Naso brevirostris	22.6	5.050						
paletail unicornfish	(75.9)	(6.253)						
N. hexacanthus	160.0	20.463			12.6	4.271	21.5	11.175
sleek unicornfish	(649.7)	(277.751)			(77.9)	(26.326)	(125.3)	(70.879)
N. lituratus	77.0	40.761			136.8	50.710	255.6	66.075
orangespine unicornfish	(119.4)	(68.696)			(177.3)	(62.022)	(439.7)	(82.973)
N. unicornis	66.4	53.804			2.1	1.122	3.9	1.349
bluespine unicornfish	(125.3)	(130.732)			(13.0)	(6.916)	(17.4)	(7.395)
Zebrasoma flavescens	4.5	0.719			440.0	45.306	1123.9	95.439
yellow tang	(18.7)	(3.146)			(477.4)	(49.145)	(949.6)	(79.219)
Z. veliferum	10.6	3.843			23.2	8.620	7.8	2.612
sailfin tang	(38.6)	(16.231)			(69.4)	(26.393)	(34.9)	(12.273)
Family Balistidae								
Melichthys niger	27.2	16.164	26.7	16.659	37.9	20.464	13.7	6.685
black durgon	(159.2)	(94.705)	(80.0)	(49.976)	(101.4)	(56.726)	(35.3)	(17.542)
M. vidua	4.5	3.319			8.4	5.708	19.5	12.010
pinktail durgon	(24.4)	(17.414)			(24.9)	(17.218)	(43.0)	(27.210)
Rhinecanthus aculeatus					2.1	0.331		
lagoon triggerfish					(13.0)	(2.039)		
R. rectangulus	36.2	6.329	8.9	1.888	44.2	8.342	2.0	0.358
reef triggerfish	(72.9)	(13.442)	(26.7)	(5.663)	(82.5)	(16.465)	(12.5)	(2.291)
Sufflamen bursa	48.3	6.038			52.6	7.762	72.2	9.980
lei triggerfish	(69.0)	(4.012)			(65.2)	(9.589)	(61.5)	(8.727)
S. fraenatus	10.6	9.161			4.2	1.873	2.0	0.307
bridled triggerfish	(38.6)	(32.396)			(18.1)	(9.138)	(12.5)	(1.963)
Xanthichthys auromarginatus					18.9	2.363	7.8	0.984
gilded triggerfish					(116.8)	(14.564)	(30.0)	(3.605)
Family Monacanthidae								
Aluterus scriptus							2.0	1.447
scrawled filefish							(12.5)	(9.266)
Cantherhines dumerilii	4.5	3.475			4.2	1.792	5.9	1.642
barred filefish	(18.7)	(14.802)			(18.1)	(7.840)	(27.7)	(7.454)
C. sandwichiensis	7.5	0.801			2.1	0.278	3.9	0.411
squaretail filefish	(23.6)	(2.584)			(13.0)	(1.714)	(25.0)	(2.634)
Pervagor aspricaudus							2.0	0.029
yellowtail filefish							(12.5)	(0.185)

Appendix B continued

Family/Species	KALA		PUHE		KAHO		PUHO	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
Family Ostraciidae								
Ostracion meleagris	4.5	0.235			2.1	0.021	9.8	0.110
spotted boxfish	(18.7)	(1.113)			(13.0)	(0.132)	(32.0)	(0.436)
Family Tetraodontidae								
Arothron hispidus								
stripebelly puffer								
A. meleagris					2.1	0.446	3.9	0.976
spotted puffer					(13.0)	(2.746)	(17.4)	(4.619)
Canthigaster amboinensis	1.5	0.031					3.9	0.125
ambon toby	(11.0)	(0.228)					(17.4)	(0.564)
C. coronata	3.0	0.049					3.9	0.060
crown toby	(22.0)	(0.356)					(17.4)	(0.270)
C. jactator	49.8	0.347	8.9	0.040	42.1	0.230	87.8	0.508
Hawaiian whitespotted toby	(83.4)	(0.586)	(26.7)	(0.120)	(60.9)	(0.335)	(126.2)	(0.734)
Family Diodontidae								
Diodon holocanthus								
spiny balloonfish								
D. hystrix					2.1	1.631		
porcupinefish					(13.0)	(10.053)		

* could not be identified to species

APPENDIX C. AVERAGE DENSITY AND BIOMASS OF MARINE FISH FAMILIES FROM SUBTIDAL TRANSECTS SAMPLED IN THE FOUR NATIONAL PARKS

Average density is given in numbers/ha, biomass in kg/ha. Standard deviation is presented below each value in parenthesis. KALA – Kalaupapa National Historical Park; PUHE – Puʻukoholā Heiau National Historic Site; KAHO – Kaloko-Honokōhau National Historical Park; PUHO – Puʻuhonua o Hōnaunau National Historical Park

Family	KALA		PUHE		KAHO		PUHO	
	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
Elopidae	120.8	<0.000						
	(879.1)	(0)						
Muraenidae	1.5	0.141			4.2	1.470	7.8	0.643
	(10.9)	(1.025)			(18.1)	(8.026)	(24.0)	(2.155)
Ophichthidae							1.9	
							(12.5)	
Synodontidae	1.5	0.001						
	(10.9)	(0.010)						
Holocentridae	24.1	4.651			8.4	0.934	138.5	13.416
	(65.8)	(15.231)			(40.7)	(4.441)	(754.7)	(70.617)
Aulostomidae	3.0	0.531			4.2	0.112		
	(15.4)	(2.888)			(18.1)	(0.554)		
Fistulariidae					2.1	0.167	1.9	0.045
					(12.9)	(1.027)	(12.5)	(0.285)
Scorpaenidae	9.1		8.9		2.1		1.9	
	(37.3)		(26.7)		(12.9)		(12.5)	
Caracanthidae	4.5	0.068						
	(18.7)	(0.339)						
Serranidae	37.7	20.702			61.1	15.392	29.3	9.614
	(72.9)	(49.134)			(91.9)	(24.418)	(49.8)	(17.009)
Priacanthidae	4.5	1.147						
	(18.7)	(5.231)						
Cirrhitidae	425.7	9.518			290.5	5.666	349.3	6.505
	(442.9)	(12.030)			(330.9)	(7.058)	(343.5)	(6.939)
Apogonidae	1.5	0.010						
	(11.0)	(0.076)						
Malacanthidae					4.2	0.083		
					(26.0)	(0.514)		
Carangidae	48.3	30.827					2.0	2.272
	(106.8)	(81.095)					(12.5)	(14.549)
Lutjanidae	176.6	38.411	35.6	3.925	235.8	56.088	403.9	28.787
	(440.0)	(84.490)	(58.1)	(6.312)	(1400.4)	(337.769)	(2496.8)	(170.395)
Lethrinidae	18.1	17.743			14.7	11.227	11.7	9.121
	(40.4)	(49.852)			(55.3)	(51.789)	(52.3)	(53.649)
Mullidae	268.7	60.795	26.7	4.470	82.1	13.496	163.9	27.048
	(322.0)	(116.199)	(56.6)	(10.084)	(97.5)	(19.081)	(534.0)	(103.047)
Kyphosidae	154.0	59.162					11.7	4.116
	(333.5)	(126.606)					(75.0)	(26.358)
Chaetodontidae	187.2	12.569	26.7	2.695	261.1	17.661	341.5	18.776
	(271.7)	(17.773)	(40.0)	(4.141)	(452.4)	(40.191)	(327.9)	(17.750)
Pomacanthidae	24.2	3.719			23.2	0.893	33.2	1.052
	(77.8)	(12.725)			(80.9)	(3.252)	(75.8)	(2.385)
Oplegnathidae	1.5	3.485						
	(11.0)	(25.370)						
Pomacentridae	3249.8	48.898	26.7	1.218	2608.4	20.990	2677.1	11.565
	(3261.5)	(71.135)	(40.0)	(2.120)	(3068.3)	(45.325)	(3048.8)	(12.304)

Appendix C continued

Family	KALA		PUHE		KAHO		PUHO	
	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
Labridae	1600.0	79.710	426.7	5.084	1218.9	28.381	1079.0	22.562
	(1173.7)	(74.007)	(676.5)	(9.128)	(694.1)	(57.662)	(463.1)	(16.964)
Scaridae	247.5	83.406	2977.8	175.388	311.6	43.334	144.4	37.955
	(284.3)	(125.843)	(4501.5)	(291.816)	(436.5)	(48.513)	(177.3)	(50.434)
Ammodytidae	4.5	<0.000						
	(33.0)	0						
Blenniidae	54.3	0.122			18.9	0.024	7.8	0.010
	(82.7)	(0.363)			(57.1)	(0.078)	(24.0)	(0.040)
Gobiidae			115.6	0.062				
			(196.4)	(0.134)				
Microdesmidae	3.0	0.002						
	(22.0)	(0.018)						
Zanclidae	37.7	4.290			23.2	3.080	5.9	0.697
	(120.1)	(13.788)			(64.2)	(8.727)	(27.7)	(3.384)
Acanthuridae	1729.8	372.549	604.4	49.891	2014.7	235.172	3346.3	319.567
	(1642.0)	(418.632)	(927.0)	(79.208)	(1511.3)	(185.569)	(1926.6)	(192.102)
Balistidae	126.8	41.011	35.6	18.546	168.4	46.842	117.1	30.323
	(196.2)	(101.564)	(106.7)	(55.639)	(178.2)	(59.158)	(89.6)	(35.297)
Monacanthidae	12.1	4.276			6.3	2.070	13.7	3.529
	(32.9)	(15.936)			(21.9)	(7.961)	(47.0)	(13.811)
Ostraciidae	4.5	0.235			2.1	0.021	9.8	0.110
	(18.7)	(1.113)			(13.0)	(0.132)	(32.0)	(0.436)
Tetraodontidae	54.3	0.427	8.9	0.040	44.2	0.675	99.5	1.669
	(84.2)	(0.680)	(26.7)	(0.120)	(60.8)	(2.728)	(131.2)	(4.735)
Diodontidae					2.1	1.631		
					(13.0)	(10.053)		
Totals	8637.0	902.778	4293.3	261.370	7412.6	505.422	8999.0	552.441
	(10138.0)	(1445.987)	(6656.1)	(458.854)	(8756.5)	(924.100)	(10751.1)	(834.222)